# Paleomagnetic Properties in Relation to the Lithology of the Minford Silts from Fairfield County, Ohio.

A Thesis

Presented in Partial Fulfillment of the

Requirements for the Degree, Bachelor of Science

by

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## Abstract

This report presents the results of a study of the magnetic properties of lake sediments, and explains the ways in which the results were used to give important geologic information. In this geophysical research project, 29 paleomagnetic cores were taken from a section of glacio-lacustrine deposits in Fairfield County, Ohio. After careful preparation, each core was analyzed for disintinctive magnetic character. Three methods were used: alernating field demagnetization, bulk susceptibility measurement, and anhysteretic remanent magnetization. Upon completion of this analysis, much previously unknown geologic information was determined. This information is in four main areas. First, it was found that there was a strong correlation between magnetic properties of the lake sediments and the lithological variation of the sediment. Second, it was found that the magnetic properties may be used to determine the sedimentary mechanisms involved in deposition. Results from this sampling indicate the possibility of organically precipitated magnetite. Third, a date of deposition was estimated from the average pole position of the cores to be approximately 8000 years ago. Fourth, a magnetic event is inferred at the base of the sampling that would suggest the earth's magnetic polarity has changed as recently as 8000 years ago.

# Glossary

1. Azimuth- The angle from due North that the plane of maximium dip angle is measured.

2. Dip- The angle at which a planar object is tilted from the horizontal.

3. Fluvial- Sedimentary deposits derived from a river or stream.

4. Geomagnetic- Pertaining to the earth's natural magnetic field.

5. Lacustrine- Sedimentary deposits derived from fresh water lakes.

6. Minford Silts- Lacustrine deposits in Ohio and Kentucky deposited by the back waters of the Teays drainage system.

7. Paleomagnetics- The study of the weak magnetic polarizations found in most rocks.

8. Peneplain- A land surface worn flat by erosion.

9. Petrographic- Pertaining to the study of rocks and minerals with the use of a polarized light microscope.

# Table of Diagrams and Figures



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# 1. Introduction

During much of the Pleistocene epoch, many of the valleys of Southern Ohio were flooded with up to several hundred feet of water. This extensive lake system was the result of massive continental ice sheets covering most of Northern Ohio. These ice sheets totally blocked the generally northward flow of the old Teays drainage system, causing these waters to build up along the southern fringe of the glacier and back up along the Teays River Valley. The combination of a drainage system from the south and the considerable amount of melt waters from the glaciers made a natural reservoir of much the Appalachian Plateau of southern Ohio.

Only ten thousand years ago the last continental ice sheet receeded from Ohio (Wisconsin Glaciation). In its wake, it left substantial glacio-lacustrine deposits covering many of the valleys of southern Ohio. The majority of the once northerly-flowing Teays drainage system now flowed south along the same stream beds that once supported them in the opposite direction.

Considering that these valley deposits are some of the best farm lands in Southern Ohio, a study of the nature of these deposits and their distribution could be beneficial. In the past, this has not been easy, because of the lack of depositional features normally used by geologists to study sedimentary materials. Many lake sediments have little or no distinctive bedding. The glacial lakes in Ohio are even harder to analyze because of their small grain size (silt to clay). This tends to make normal petrographic analysis impossible.

Recent advances in the use of magnetic methods have significantly augmented the study of such sediments. By the studying the magnetic properties of otherwise almost undetectable grains, one can determine much about geological history of many lake sediments.

During the last ten years, the studies of the paleomagnetic and rock magnetic properties of glacio–lacustrine sediments have been used to determine recent variations in the earth's magnetic field and to determine sources of influx in various lake sediments. [Liddicoat], [Strangway], and [Noltimier] have all recently used paleomagnetics in conjunction with C-14 dating to study recent variations in the geomagnetic field. **Although** there has been little collaboration between geologists and paleomagnetists, there have been several variations in the geomagnetic field discovered in the last twenty years. The last major geomagnetic reversal ,known as the Laschamp, has yet to be properly dated; and other short lived reversals have been detected as recently 12,000 years ago. [Foster] attempted to show a direct correlation between these events and major changes in the earth's temperature. [palmer], [Stober], and [Oldfield] have begun to use magnetic methods to extrapolate unseen lithology.

In this study I am investigating the temporal variation of magnetic properties in a 3 meter section of glacio-lacustrine sediments by employing three basic techniques: A. F. demagnetization, bulk susceptibility, and anhysteretic remanent magnetization.

## 2. Magnetic Theory

The basis for geomagnetic theory is the creation of a dipole electromagnetic field by any elementary current loop. This dipole field is of similar nature whether it is caused by a conducting loop, an electron circling a nucleus, or a molten iron core of a planet [McElhinny].

Within the core of the Earth, large heat gradients power toriodal and poloidal convention cells. These cells give rise to the strong poloidal dipole field of the Earth.

In nature a given rock sample with an internal magnetic moment, will give off a dipole field simular to that of the Earth; but on a much smaller scale. The total intensity of magnetization for a standard core sample are measured in units of *emu cm-3*. This total field is composed of two separate parts; the remanent magnetization, which is the part of the field that remains after the removal of a sample from an external magnetic field, and induced magnetization, which is the magnetic field that is present only if a sample is surrounded by an external field. This can be represented by the equation,

$$J = Ji + Jn$$

where J is the total field, Ji the induced moment, and Jn the remanent moment The induced field is proportional to the applied field H,

$$Ji = xH$$

where $x$ is a constant of proportionality called the bulk magnetic susceptibility. This magnetic susceptibility is vectorless and unitless; but is an easily measurable constant that has a distinctive value for various minerals and concentrations of these minerals.

Of more interest in paleomagnetics is the remanent moment itself, which is commonly represented as unit vector with a given scalar strength. The parallelism of this field with a pre-existing external field under certain conditions that provides the greatest amount of information to geophysicists. A standard example of this affect can be noticed when looking at the magnetic field over the Atlantic Ocean. It was found that there are parallel bands of opposingly magnetized basalts on both sides of the mid-Atlantic ridge. This led to a dramatic application of the earlier discovery that the Earth's magnetic field is not constant. The field has spontaneously reversed itself quite often in the past. and these and other irregularities in the field have been recorded by magnetic grains within many rocks and may be used to determine the paleolatitude and ages of rocks.

There are three fundamentally different types of magnetic behavior responsible for the remanent magnetization in minerals. These magnetic behaviors are diamagnetism, paramagnetism, and ferromagnetism (McElhinny 1973). The first two, diamagnetism and paramagnetism, are both very small and will not be considered in this experiment; ferromagnetism is responsible for the magnetism in my samples. Ferromagnetism is caused by unpaired electrons in incomplete electron shells of an atom. Ferromagnetism is most common in elements of the iron group (iron, nickel, cobalt, manganese). These elements make up the many ferromagnetic oxides. Magnetite has the most intense magnetic moment of ferromagnetic oxides and is the most common magnetic mineral in the samples measured in this experiment. The next strongest magnetic material, hematite, is less then 1/20 as intense as magnetite and is usually formed as a secondary weathering product in warm climates. This will be dealt with more thoroughly in a later part of the paper.

When a natural event such as sedimentation or cooling from a molten state occurs, a rock or soil containing ferromagnetic minerals acquires a magnetic moment. The existing geomagnetic field is recorded by particles as they settle through a fluid and are held in place by clastic grains or surrounding crystals.

There are four types of remanent magnetism found in rocks: Thermal Remanent Magnetization (TRM), Chemical Remanent Magnetization (CRM), Viscous Remanent Magnetization (VRM), and Detrital Remanent Magnetization (DRM). The main type of magnetization seen in my samples is DRM. which results from the settling of ferromagnetic particles in a fluid medium. The alignment with the field occurs during the time the particles sink through the fluid, and during compaction after sedimentation while the mass is still viscous. This can also be called Post Detrital Remanent Magnetization (PDRM). The accuracy of this record is dependent on the depth of the fluid through which the grains fall, and any flow in the water which is great enough to affect the natural anisotropy of the grains or to disturb previously deposited layers. Both sources of error are very small in quiet lacustrine environments. This makes many lacustrine deposits excellent for studying variations in the geomagnetic field.

# 3. Sampling

There are numerous remains of glacial lakes throughout southern Ohio, of both Wisconsinian and Illinoian age. During the Spring of 1984, I made the first of several trips looking at the extensive lake deposits in the lowlands of Hocking and Fairfield County. Using a glacial map of Fairfield County and several local contour maps, seven likely spots for undisturbed lake sediment were chosen for investigation. All but two of these sites showed extensive vertical soil cover (over three feet). This made suitable paleomagnetic material unreachable without a soil auger. This also presented the problem that the lake sediment may have been seriously altered. The last two sites showed little alteration of the lake deposits and were also well exposed due to recent stream erosion. The first of the sites showed an interesting pattern of a thin bed of lacustrine layers enclosed, above and below, by two thick intervals of fluvial deposits. However, the lacustrine sequence was too thin to permit good paleomagnetic sampling.

The final site, and the one that was used for sampling, was on the border of the small town of North Berne which just to the west of Lancaster (See diagram 3.11 for exact location). The small stream from which the cores were taken was less than 10 feet to the west of the intersection of state route 10 and 235. The coordinates of the site are latitude 42.500 degrees and longitude 83.500 degrees. In diagram 3.12 one can clearly see the general nature of the topography of the valley where the samples were taken. This also can be seen in diagram 3.21 which is a photograph of the area.

A five foot vertical trench was dug to expose sediments that had not been affected by flooding of the stream or chemical weathering from exposure to the atmosphere. Twenty nine samples were taken from a base 153 inches above the water line. Samples were removed along the entire section at approximately five inch intervals using hollow plastic cores which were carefully driven in perpendicular to the trench wall. Each core is one inch in diameter and one inch long, and the group were numbered from 0 to 29 (note that core 21 was lost in sampling). Before removal from the ground, each core had its dip and azimuth recorded using a Brunton compass resting on a flat plate connected to a hollow metal tube. Immediately after each core was carefully removed from the surrounding soil, it was cleaned of all excess dirt and put in a separate plastic bag.

In order to prevent alteration and possible CRM due to dehydration, each core was quickly capped with a thin but air-tight layer of paraffin. All samples were subsequently stored in a refrigerator to further keep dehydration down before full A. F. demagnetization was finished.

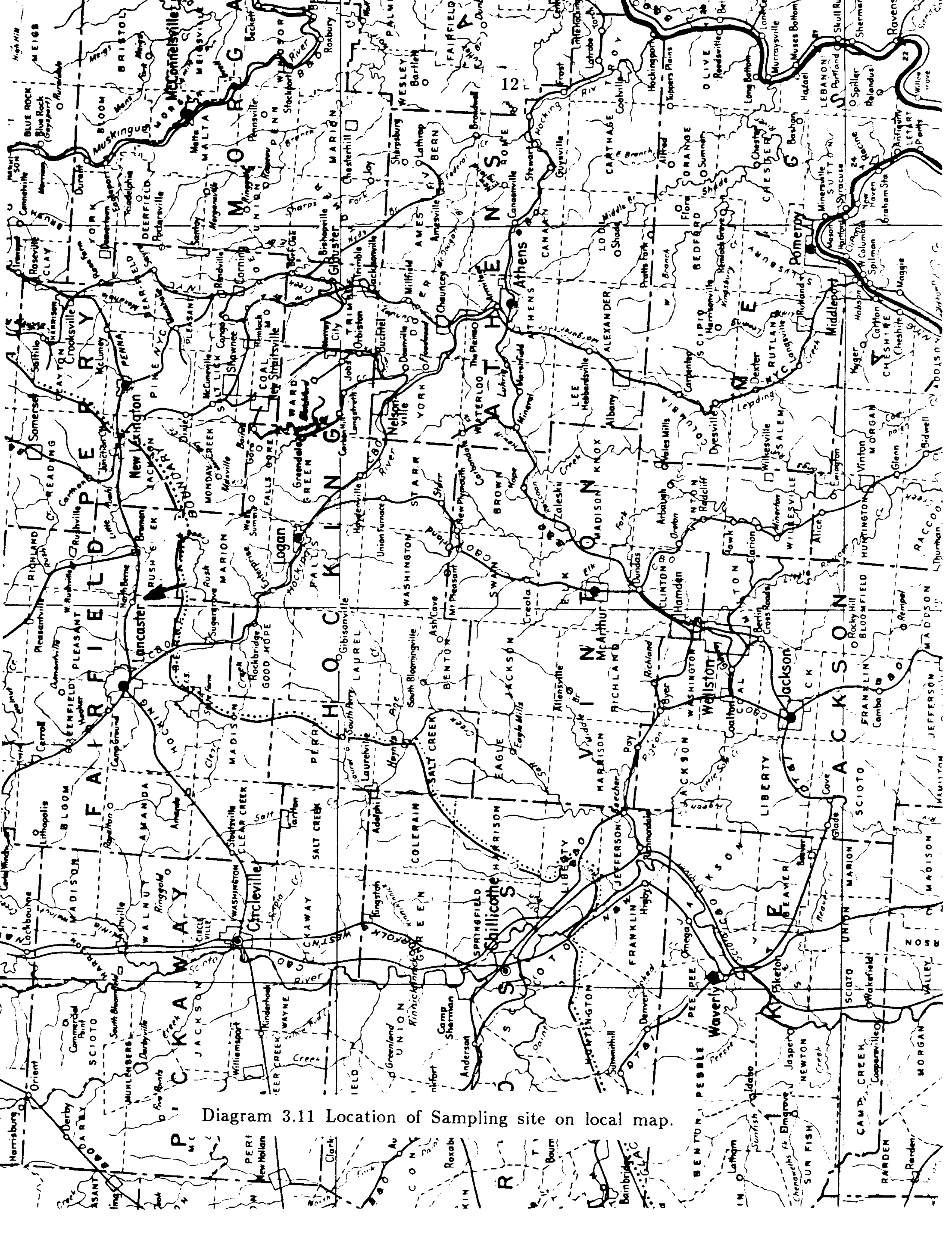



Diagram 3.11 Location of Sampling site on local map.

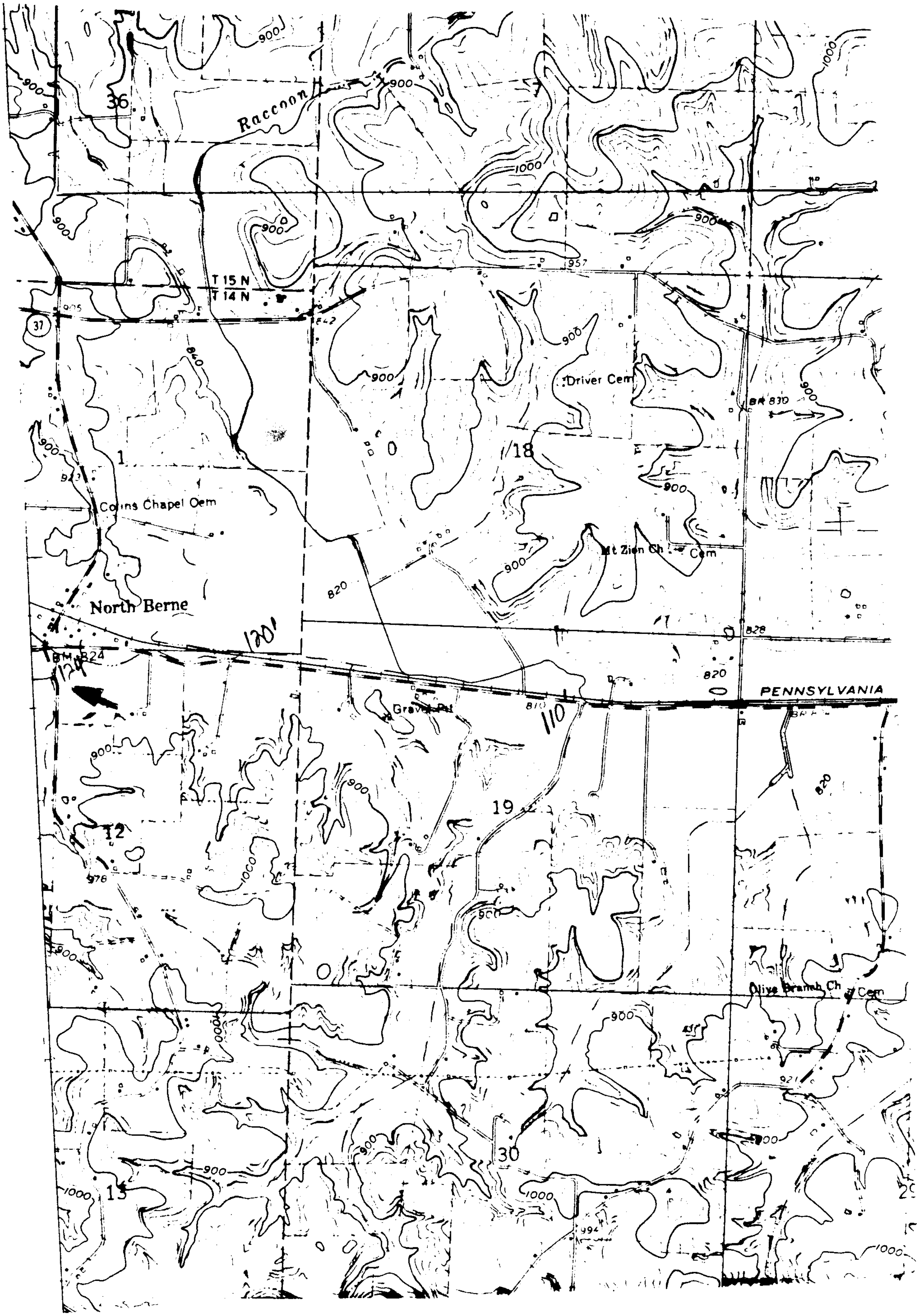



Diagram 3.12 Topographic map of the Sampling site.

Diagram 3.21 Pictures of the site and surrounding area.

3.21 Picture of Site

# 4. Background Geology

## 4.1. Pre-Pleistocene Geology

There were two major sources of sediments in the pro-glacial lakes of the Minford deposits. The first is the sediment in the direct run off from the glacier. The second is sediment derived from the Teays drainage pattern, which was dominated by sediments in turn derived from the regional country rock.

For this reason it is important to understand the pre-Pleistocene stratigraphy of the prominent country rocks and how they would contribute to deposition of these lacustrine deposits.

The most important contributor of sediments to the glacial lakes are probably the resistant beds of the Cuyahoga formation. From the rocks of the Cuyahoga formation it appears that most of Ohio was once covered by a shallow sea environment (the Waverly Sea) during most of the Mississippian period. This is clearly seen by the thick and continuous shale members of the Cuyahoga formation. These shales consist primarily of interbedded, fine grained, thin sandstone and of grey silicious shales, with the shales being considerably dominant over interbedded sandstones. Within the grey shale there is abundant mica, which is found concentrated in thin layers and lenses scattered throughout the rock layers. The rare sandstone layers appear to be solely due to localized events and consist primarily of fine grained quartz particles.

Entering the Waverly sea from the south were the relatively chaotic deposits of the Blackhand delta system. The Blackhand sandstone is dominantly a gritty, friable, coarse-grained sandstone containing many lithic pebbles. Most are comprised primarily of quartz, both white and dark; but some grains of jasper, feldspar, and abnormally large grains of magnetite can be found. The pebbles commonly are one one-eighth to one-fourth of an inch in diameter, but it is not uncommon to find pebbles as large as one inch in diameter. The matrix is most commonly cemented together with a silicious cement with local pockets of limonitic cement that is derived from the abundant iron oxides in the sandstone.

These sandstones and conglomerates are abundantly cross-bedded and are directionally coarsening **upward** with a slope to the north. This attests to the fact that portions of Vinton, Hocking, and Fairfield county were all areas of heavy rapid sedimentary accumulation. In the past this has been attributed to rapid delta growth under very strong braided fluvial action, but more recently it has been proposed that they are due, at least in part, to sandbar accumulation under very strong oceanic current flowing along the slope of the basin, much like deposition in southern California today. The paleo-fluvial source for these sediments has been referred to as the Styx river, which would have found its source waters to the southeast in the then young Appalachian mountains. Looking at the minerals of the Blackhand, one would expect a provenance dominated by igneous materials [Hyde].

After the relatively active Cuyahoga deposition, there was very little active sedimentation in Ohio that would produce noticable amounts of magnetite.

### 4.2. Pleistocene Glaciation

The other main source of sediment to the Minford silts was the glacial outwash from the four major glacial advances [Hall]. Because of the tendency of most major glaciers to deposit large amounts of erratic material, it very possible to find sediments foreign to Ohio being deposited in front of glaciers. It is therefore plausible that there would be relatively large amounts of igneous and metamorphic material found in lakes near glaciers. This could be very useful in determining provenance in most glacial lakes, but here this is not the case because the Cuyahoga run-off has the same effect.

### 4.3. Pre-Pleistocene Erosional Cycles

Observing the topography in most areas of southern Ohio, one can discern that the tops of all the local hills mark a nearly flat surface, with the height of the peaks varying from 1060 to 1200 feet above sea level. It has been postulated that this is an old erosional surface referred to as the Lexington-Worthington Peneplane [Hohler]. Though the idea of widespread peneplanes has fallen out of favor with the ascendance of plate tectonics, it is still very plausible geologically that there may have been a peneplane in Southern Ohio as recently as the Pleistocene. At some point in time during the late Quaternary, there was a regional uplift, rejuvenating the old Lexington-Worthington Peneplane, raising the drainage system over one-hundred and fifty feet. The remnants of the older peneplane are collectively called the Parker Strath. The drainage system it created was the Teays.

### 4.4. Pleistocene Drainage Patterns

Probably the most important change in the drainage of Southern Ohio has been the apparent flow reversal in most of the area streams. These reverse drainage flows are the last remnants of the Teays drainage system. The Teays river may have cut through the Piedmont of North Carolina and Virginia, through the path of what now is the New River. It flowed northwestward to Charleston, West Virginia, then westward across Cabell and Putman counties in the present valley of the Ohio river at Huntington, West Virginia. It followed the course of the Ohio to

Wheelersburg, and from there to the now abandoned Waverly channel to the present course of the Scioto river.

The next drainage, Deep Stage, was inaugurated by the advancement southward of the Kansan or a pre-Kansan glacation into Ohio. This impounded the waters of the ancestral Teays drainage system in south central Ohio near Chillicothe. The damming of the river system caused the formation of a natural reservoir, Lake Tight, that formed lacustrine slack waters up to two hundred miles up-stream. The extensive lacustrine deposit left by these waters is known as the Minford Silt Member. After a substantial period of deposition, the breaching of natural divided drainage systems drained the lakes and established a southerly flowing drainage system. This new river so formed is known as the Newark river. With the advance of the Illinoian glaciation even farther south than the Kansan, even more of the streams of the area were blocked. Many streams that had not been affected by previous glacation now had head waters blocked and formed new lakes. The silt deposits from these lakes are also generically known as the Minford Silts. By the time of the most recent glacation most of the of streams in Ohio flowed in a southerly direction. When the Wisconsin finally retreated from Ohio, it left relatively little effect on the local drainage patterns.

The drainage system of the post-glacial Holocene is a dendritic one that has little structural control on outside streams due to the nearly horizontal nature of the local bedding beds. Streams tend to flow to the southeast toward the modern Ohio River.

### 4.5. Lithology of Minford Silts

The lithology of Ohio glacial lake sediments varies greatly across most of Southern Ohio. The majority of the Minford Silts still show a strong varving of rhythmic fine grained sediments sometimes referred to as rhythmites (banded clays). These are due in part to seasonal variation of glacial run-off in areas where a periglacial climate would prevent seasonal overturn. This rhythmic nature is strongest the nearer one gets to the glacial front, where the increased deposition during the warm months of the year is most strongly felt.

This pattern can be altered by many contemporary sources as well as outside effects. An important effect in some sediments is bioturbation. This should be readily recognizable by an extensive paleo-soil (brown clays). Turbidity currents can also cause the randomization of previously aligned clays. During deposition, provenance can also play a prominent role. As one gets farther away from the local glacial front, and closer to local drainage streams, one sees a loss of seasonal varving and sedimentation becomes dominated by the more continuous water output (grey clays). This could also indicate the amount of glacial outwash found as compared to sediments derived from country rocks.

Some lakes may not have drained during the glaciation period and stayed active for some time afterward. In these cases one would expect to find evidence of eventual eutrification as the water temperature rose and organic activity increased (black clays).

## 4.6. Conclusion

Little research has been conducted directly on the substantial glacial lake sediment that cover large amounts of Southern Ohio. This is surprising considering the importance of these sediments in local farming and the use of these clays as landfill material throughout Ohio. It could be very useful in the future to have a categorical mapping of these sediments by composition and source, noting which lake clays are of the most economic use, locating known deposits, and locating places where they are likely to be found.

# 5. Laboratory Procedure and Equipment

## 5.1. Alternating Field Methods

The first thing done to the cores after they had been capped with parafin was to dry the wax caps over night. They were then, one at a time, mounted in a plastic cubic sample holder. Each core then had its initial magnetic remanence measured in 6 axial directions. This was done on a Schonstedt SSM-1A Magnetometer by spinning each core inside a multi-layer magnetic shield. The rotation produces a small electronic current that is detected by a ferrite sensor. Two self-contained coils are used to null any residual field inside the shield. The magnetization intensity in the x and y planes for that spin can then be recorded (in microgauss). This provides 12 readings for each core, consisting of four separate measures of the three magnetic vectors in terms of x, y, and z axes of the sample. This data can then be analyzed for sample magnetic direction ,intensity, and statistical consistancy.

Core numbers 0,6,12,18,24, and 29 were then demagnetized at increasing stronger levels: 20,45,70,100,150,200,250,300,400,500,600 oersteds *(Oe)*, using the Schonstedt GSD-1 demagnetizer. During each demagnetization treatment, every core is cleaned in a controlled alternating field along the x,y, and z axes. They are then spun in all six positions to determine each core's residual magnetic moment. Each succeedingly stronger demagnetization treatment would remove the softer and more viscous parts of the total magnetic moment. These viscous moments are often acquired after the DRM is acquired; they can be caused by such spurious activity as stress, lighting, and chemical alteration.

These original six cores served as a pilot suite, which was used to determine the demagnetization stages which are statistically best to treat the remainder of the cores. This was done by plotting the total moment of each core versus the entire range demagnetization field intensities. From these results it was determined at what point the unstable viscous moment disappeared. From these graphs the optimum demagnetization pattern was determined for the remainder of the cores: 0,45,100,150,200, 250,300,400,600 *Oe*

### 5.2. Bulk Susceptibility

The bulk susceptibility for each core was measured with a Soiltest MS-3 Magnetic Susceptibility Bridge and a Tektronix type 545 Oscilloscope. Because of the very small susceptibilities of the cores, they were measured overlapping with sets of three. Doing core 1-2-3 then 2-3-4, 3-4-5... until the entire suite of lake bed cores were measured. For each set the bulk susceptibility was determined from the equation $x$=BMS= (Balance setting- Sample reading) x(7.6 E-6)/3. The results were then plotted against sample number/elevation.

### 5.3. Anhysteretic Remanent Magnetization

After all samples were completely demagnetized at 600 *Oe*, anhysteretic remanent magnetization was used to identify remanence carrying phases and to evaluate the magnetic grain size distribution among the cores. This was done through the induction of an anhysteretic remanent magnetization (ARM), which is done by placing each core in a strong AF demagnetization in the presence of a weak DC field. The apparatus used for ARM induction consisted of a ten turn coil loosely wrapped around a hard plastic core holder. This was placed in the solenoid of the GSD-1 demagnetizer, connected to a Power Design Model 2005A voltage source which produces a 0.10 *Oe* field in the specimen. This produced a single axis magnetization of the ferromagnetic phase. These newly magnetized cores were then demagnetized as before, but only along a single axis.

# 6. Data Reduction

## 6.1. Determination of Pole Positions

Pole positions were computed for each demagnetization stage of each core. This was done on an IBM 370 mainframe with a program written in FORTRAN to reduce the 12 data points for each core with a specific geomagnetic paleo-pole position. Results were determined in terms of inclinations and declination on a Wulff net.

## 6.2. Determination of Optimum Alternating Field OAF

Four independent methods of measuring reliability were used to determine the optimum pole-position for each core:

### *6.2.1. Briden Stability Index*

The BSI has been used extensively since 1972 to determine the optimum magnetic field for cleaning and the truest representation of the actual remanent field. The stability index S is defined by S1-2=[1-(J1-J2)/J1] where J1 and J2 are two respective vectors. If S=1, then the two vectors are equal, and if S=-1, then the two vectors are equal and anti-parallel. Thus when S values are closest to 1 they indicate the best cleaning stage. The validity of BSI is dependent on three factors: 1. The direction of each vector must be known; 2. The residual moment must be measured in successive stages of demagnetization to allow linear interpolation; 3. The alternating field must be increased in specific alternating steps. All three conditions can be met by my sample data.

### 6.2.2. Fractional Total Moment J/J0

*J/J0* For each core the vector of the magnetic field was determined from 12 component spinner data; from this, an inclination, declination, and total magnetic moment were determined. This statistical measure looks solely at the total magnetic moment. J/J0 is a measure of each core's field strength normalized to the Normal Remanent Moment (NRM).

### 6.2.3. P-Stability Index

More recently, a new vector stability index was purposed by [Symons]. The PSI represents the magnitude of the derivative of the remanence direction with respect to the AF intensity of the demagnetizing field. Physically, this is the change in the remanent magnetic field in millidegree units per *Oe* at each AF position. By this method the PSI curve for a core can be used to isolate the best stable remanence direction.

### 6.2.4. Fractional Vector Variation R/N

The final test examined the variability in the actual readings themselves. If you consider all possible variations in the 4 readings of the three axis of each core, you find 64 possible variations. The optimal variation being where all 4 vectors are identical. For each core a goodness of fit number from 1-64 was determined for each demagnetization reading. These values were then divided by 64, making them an easily graphed quality index, 1 being perfect agreement.

All four of these methods were plotted for each core, and the demagnetization stage having the optimium combination of these factors was used for calculating the best site pole position, from here on to be referred to as OAF.

# 7. Discussion

## 7.1. Optimium Alternating Field OAF

The graphs in Appendix 1 show the four measures of OAF determination used for each core: J/J0, PSI, BSI, and R/N. The optimium field is one that has the lowest reduction of the total field strength J/J0, while removing the maximium amount of visious moment. To determine this, all four graphs are compared. Low values of PSI and high values of BSI, corresponding to a high value of R/N, indicate the best possible statistical value for any core. If this value is located above the half way point on J/J0 (the Median Destructive Field, MDF) and lies on a smooth decay curve, then the OAF derived for that core can be considered a statistically very accurate estimation of the pole position during the time of deposition.

Analysis of OAF data of cores 000 and 001, show that both cores have very weak magnetic remanance and very erratic demagetization curves. For this reason the rather erratic pole postions calculated for these two cores were not considered in any overall trends. All of the remaining cores show very consistent magnetic behavior, with pole postions showing an accurate representation of the actual magnetic alignment of grains in each core.

## 7.2. Determined Pole Postions

Three sets of Wulff nets of pole positions determined from A.F. demagnetizations, were drawn up.

### *7.2.1. Pole Positions by Demagnetization Stages*

Figures 7.21-7.29 present the pole positions plotted on Wulff nets that have been sorted as to thier successive demagnetization stages. The results show a definite clustering of pole positions at about 80 degrees in declination on the north-south plane. This pole position is about ten degrees off the present geomagnetic field which indicates a deposition date of at most 10,000 years B.P.. However, there appears to be a slight trend toward a reverse pole position in several of the cores. As to whether this represents an actual trend is hard to say looking at these initial plots. Because this trend seems to increase in clarity with each successive stage of demagnetization, I felt more investigation was needed.

Figure 7.2.1
Stage 000



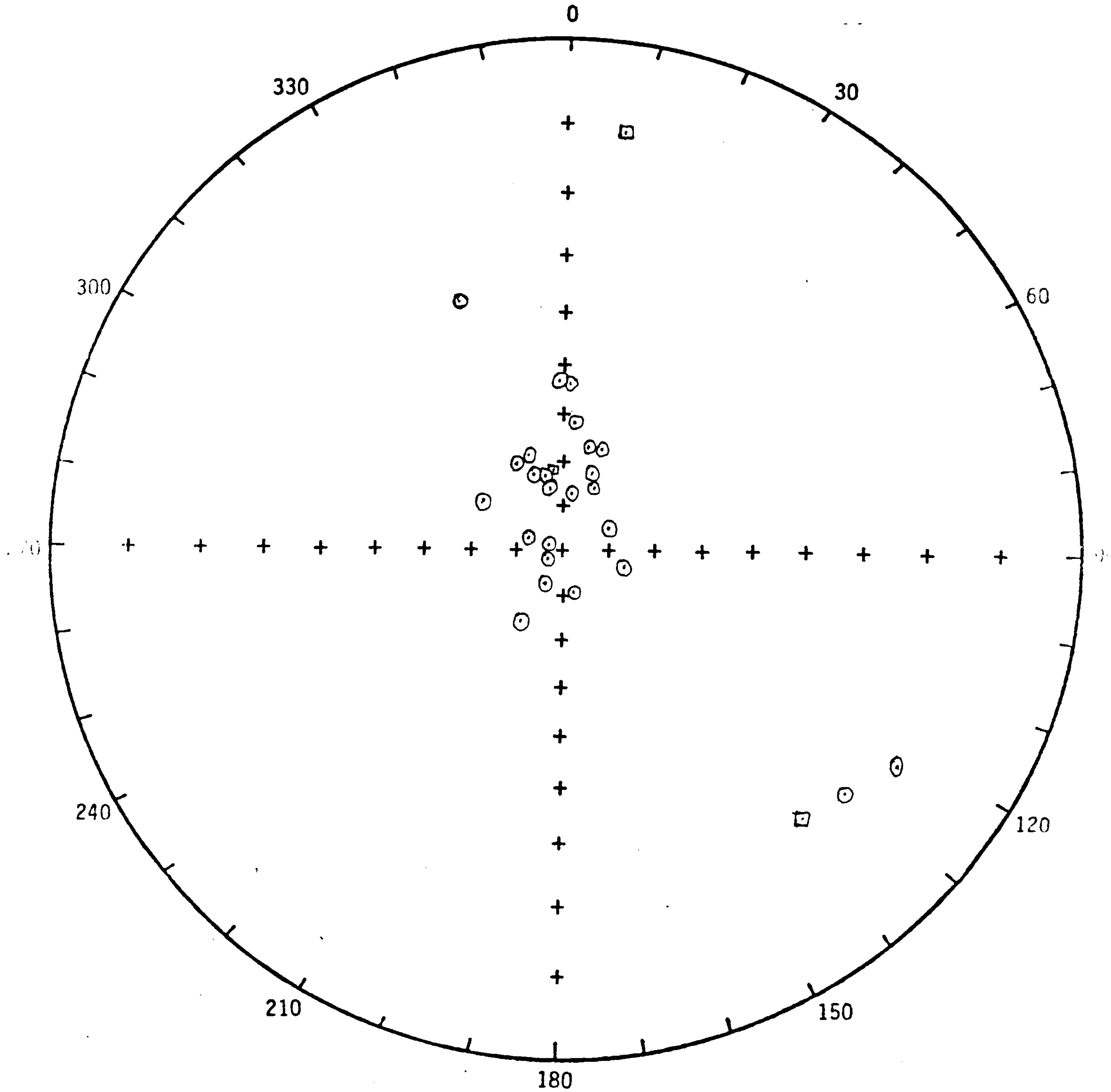


Figure 7.22
Stage 045

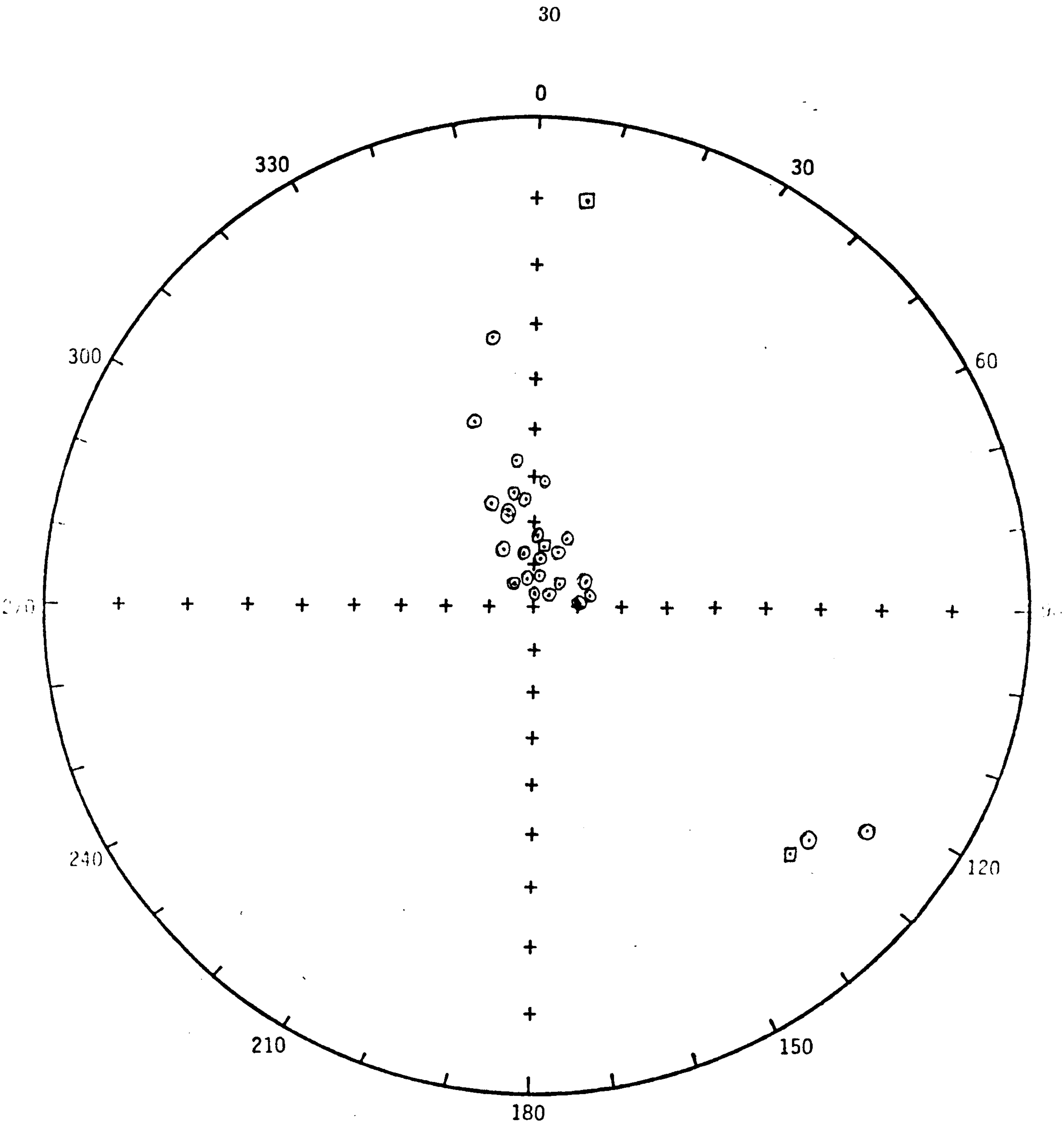


Figure 7.23
Stage 100



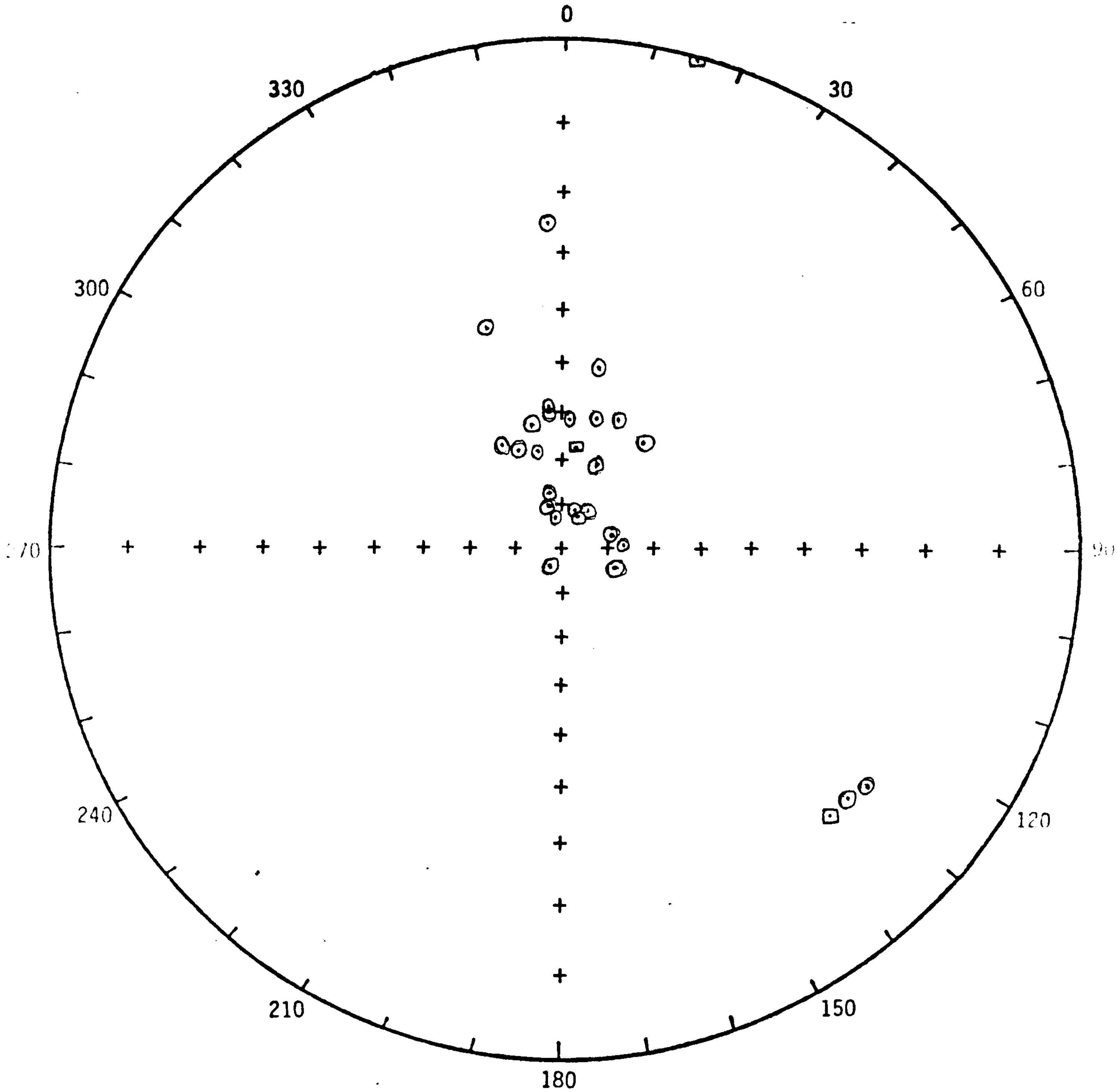


Figure 7.24
Stage 150

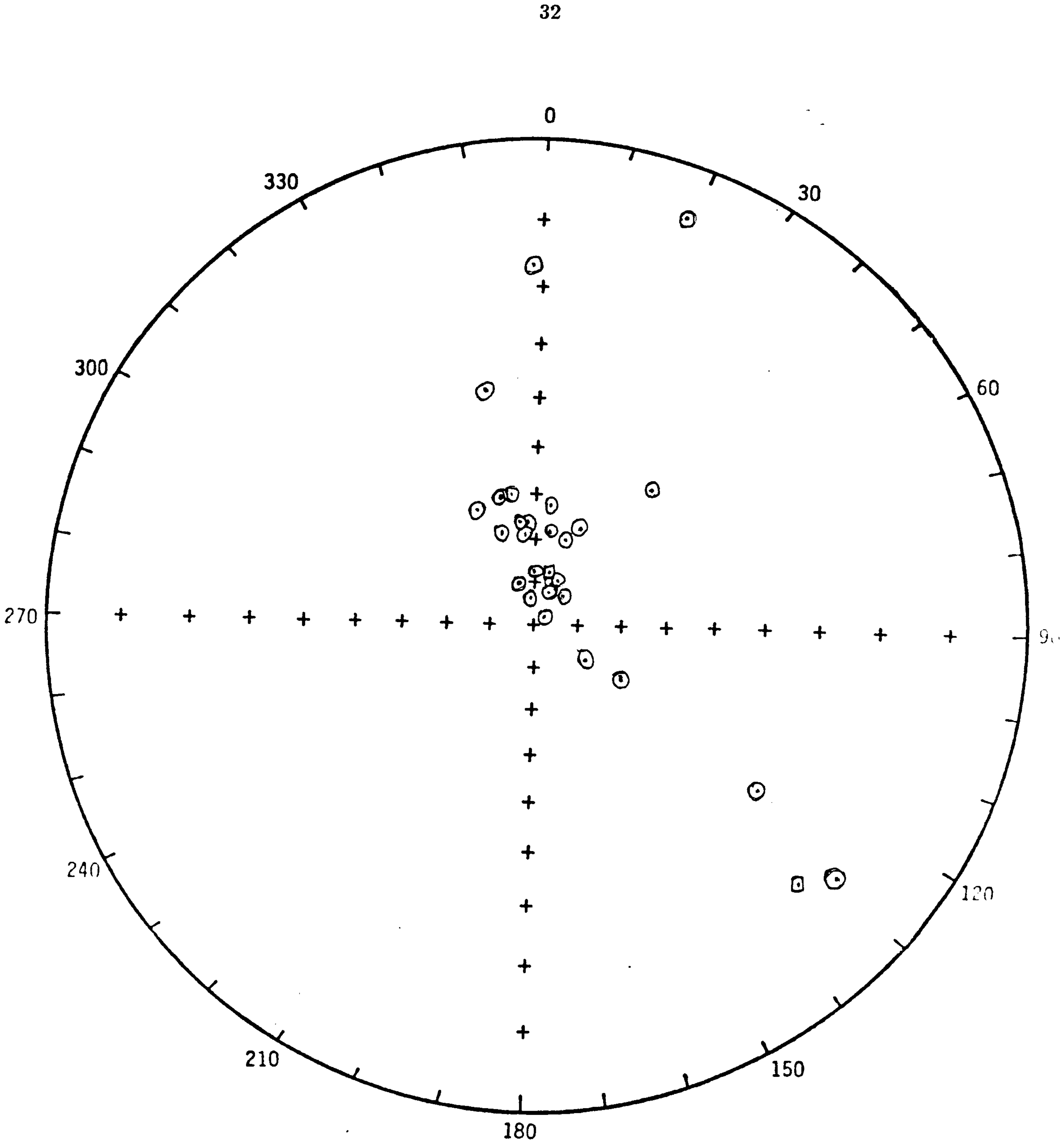


Figure 7.25
Stage 200



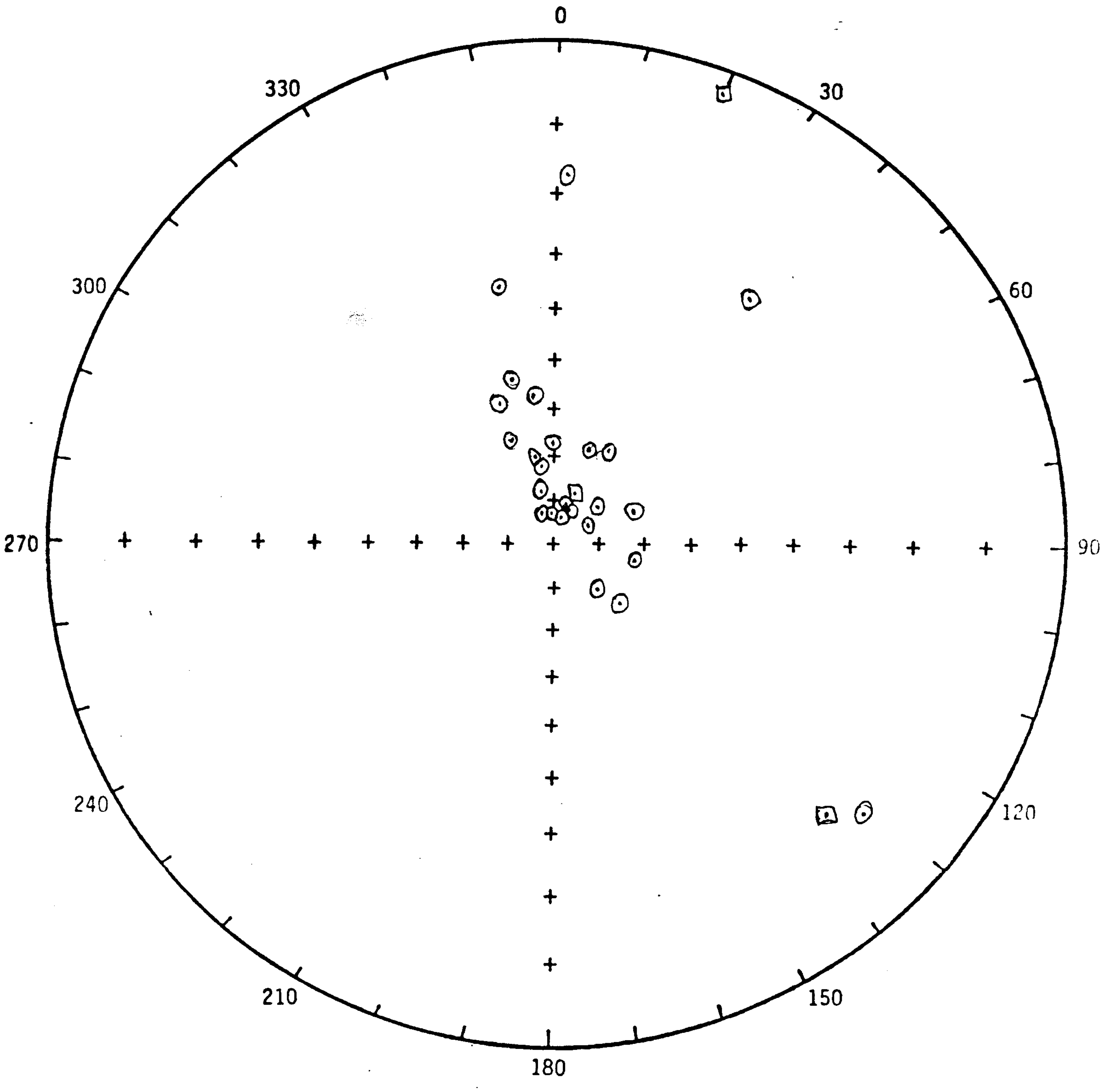


Figure 7.26
Stage 250



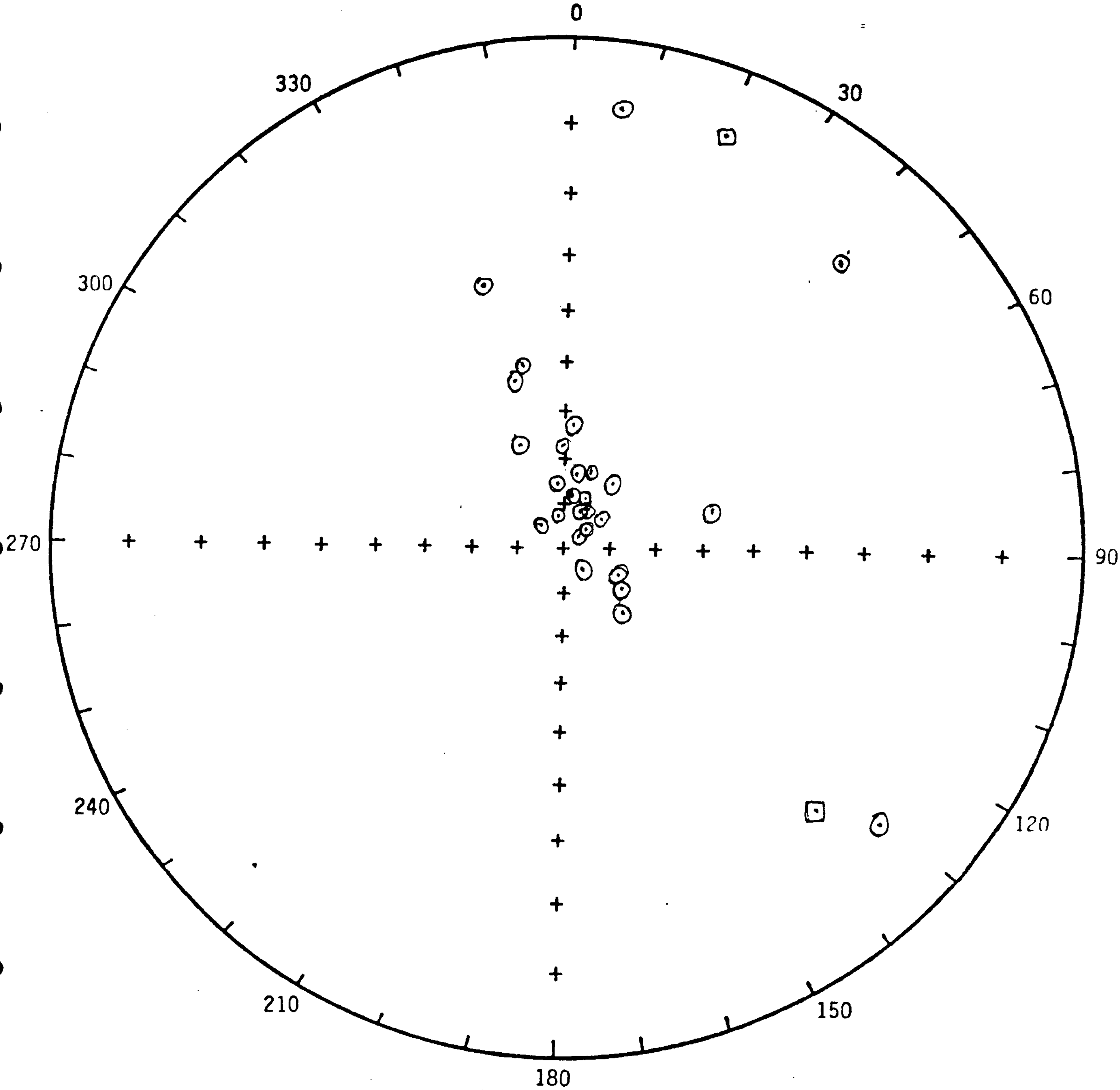


Figure 7, 27
stage 300



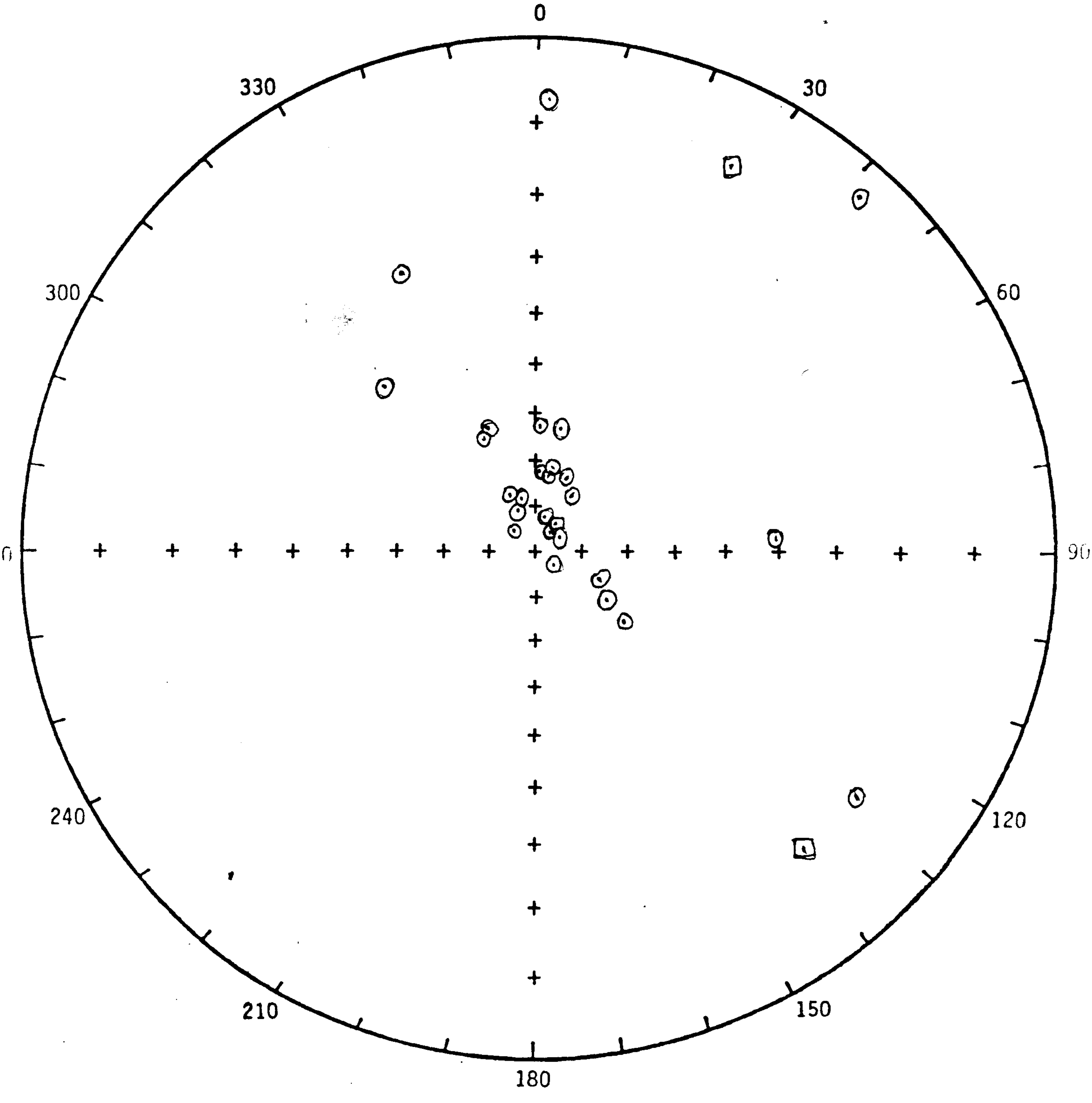


Figure 7.28
Stage 400



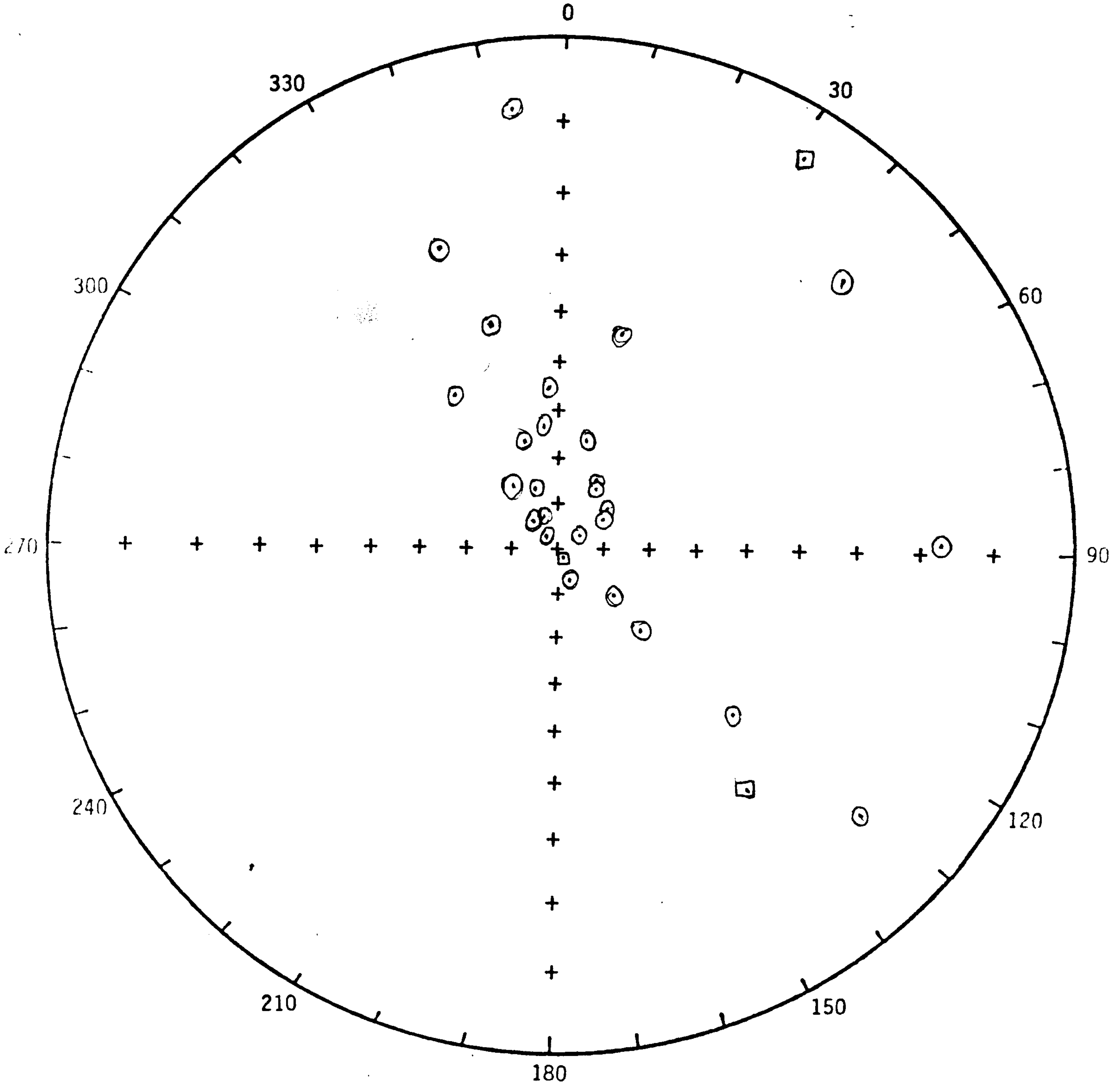
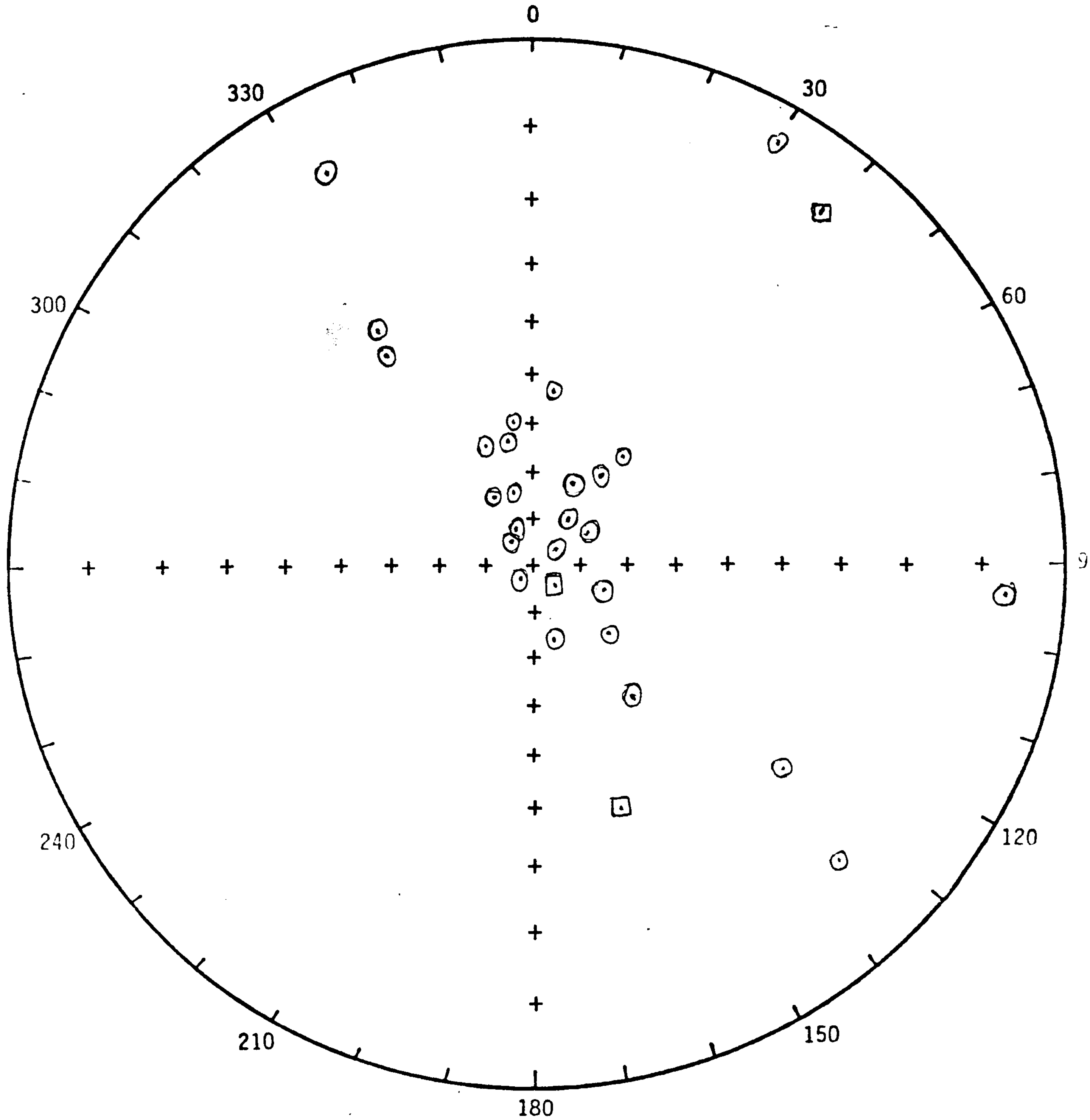


Figure 7.29
stage 600

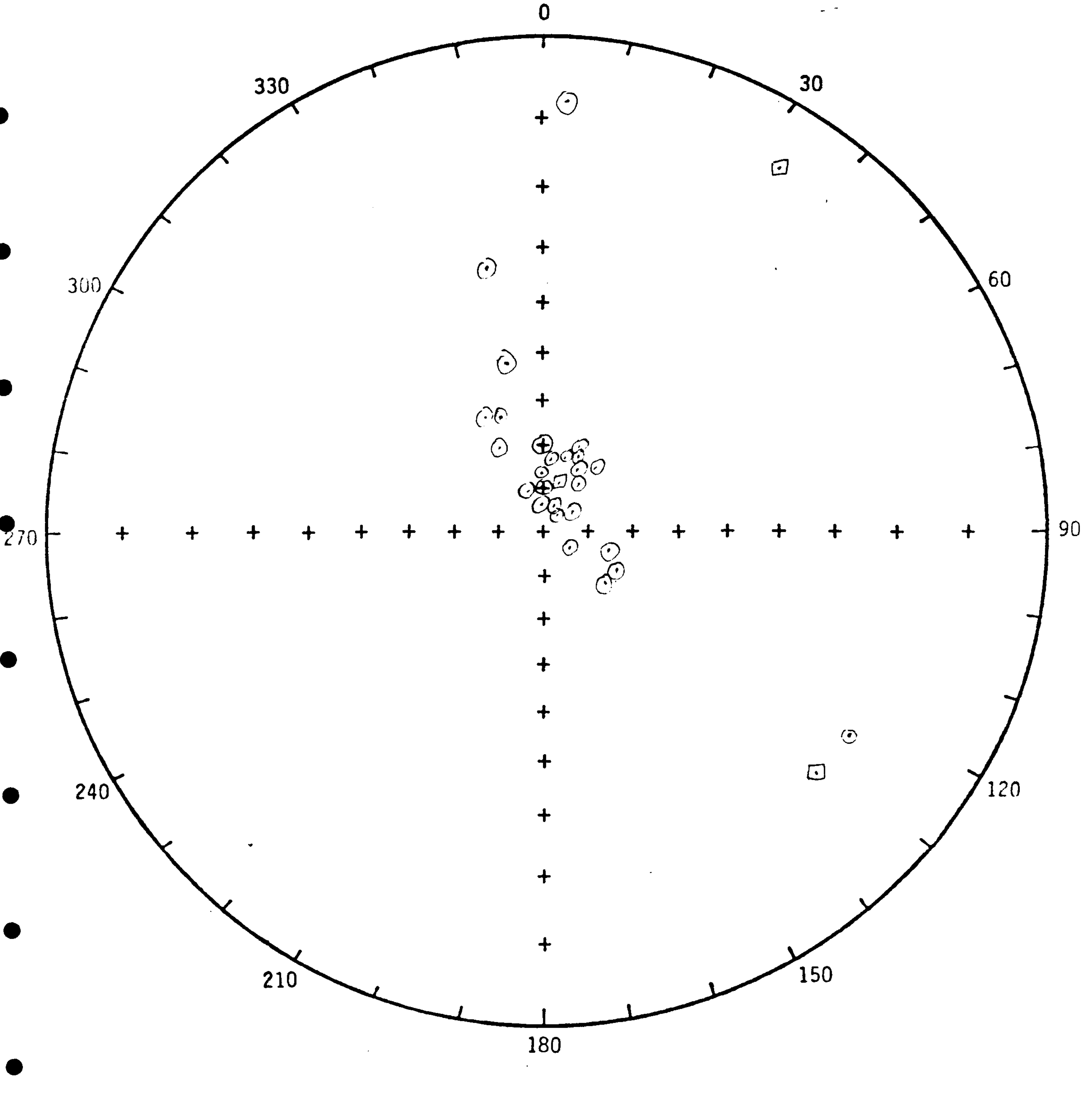




### *7.2.2. OAF Pole Positions*

To further clean the data, a plot of all the OAF positions was made on figure 7.22 As discused earlier in this paper, the OAF poles represent the most statistically accurate pole for each core. With this further cleaning, the magnetic event showed up with increasing clarity.

Figure 7.22
OAF pole positions



*7.2.3. OAF Pole Positions Separated by Lithology*

Figures 7.2301,7.2302, and 7.2303 were made to specifically locate this event on some sort of stratigraphic time scale. The OAF field positions were separated into three separate groups, each representing a different phase in the lake's deposition. Cores 0-12 represent the bottom of the sampling section (Greyish brown clay), cores 12-19 are the middle of the section (Black clay), and cores 20-29 represent the uppermost lithologic unit (Brown clay) (see glacial lake lithologies earlier in this paper). This separation showed that the magnetic event was limited to the lowest lithological layer of the sampling.

Figure 7.301
VAF pole positions
Bed 1



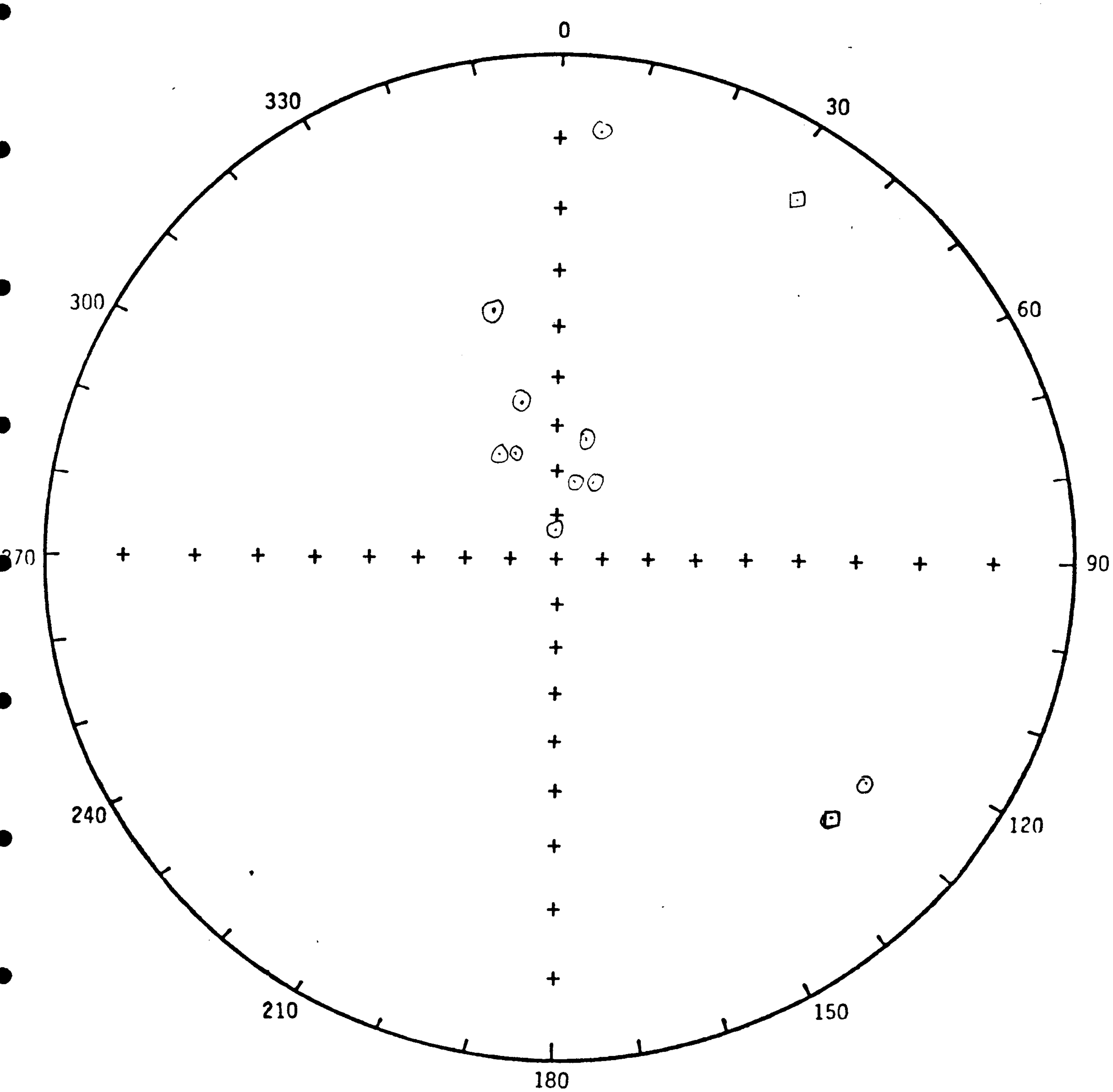


Figure 7.302
OAF pole positions
Bed 2



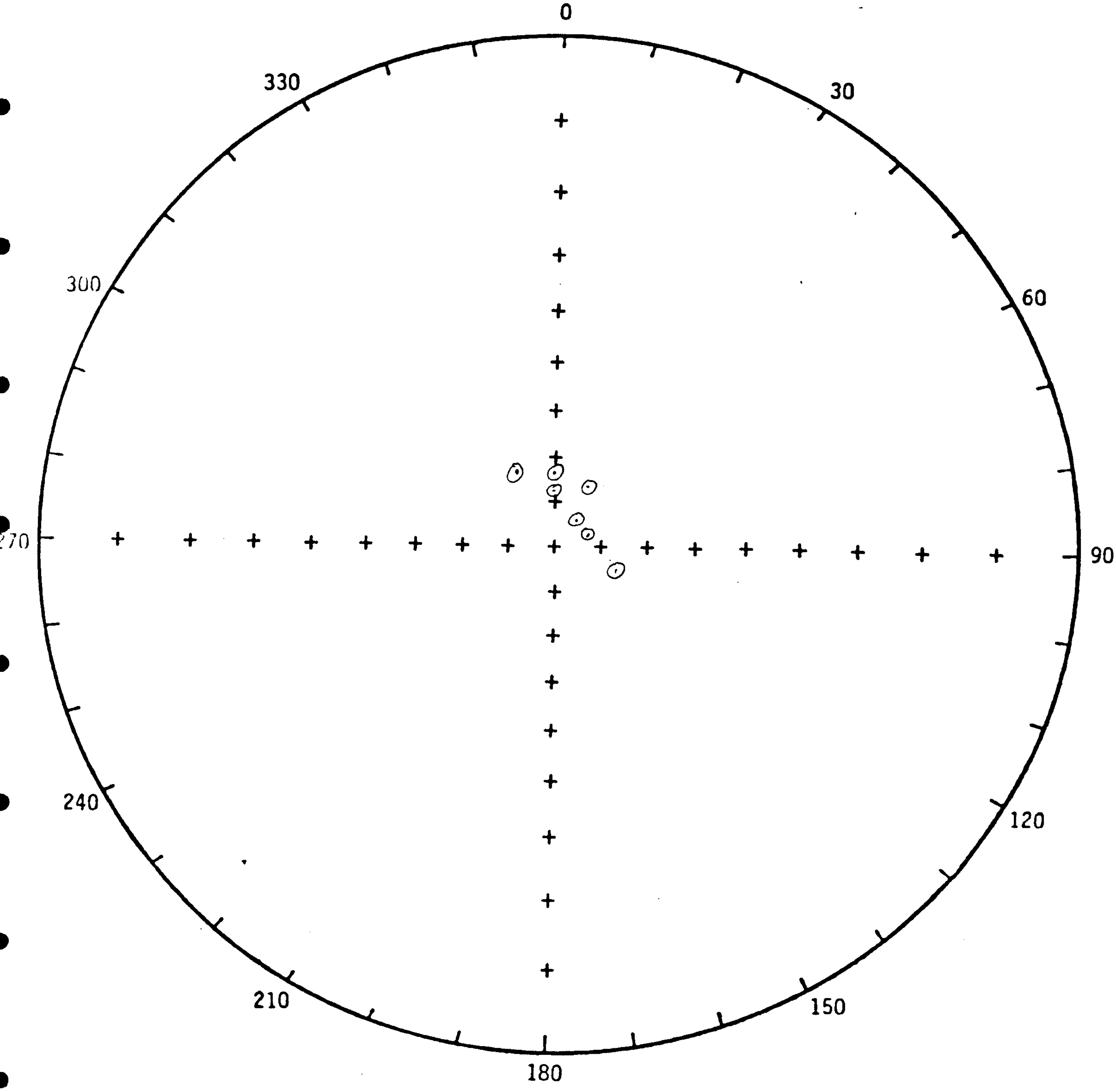
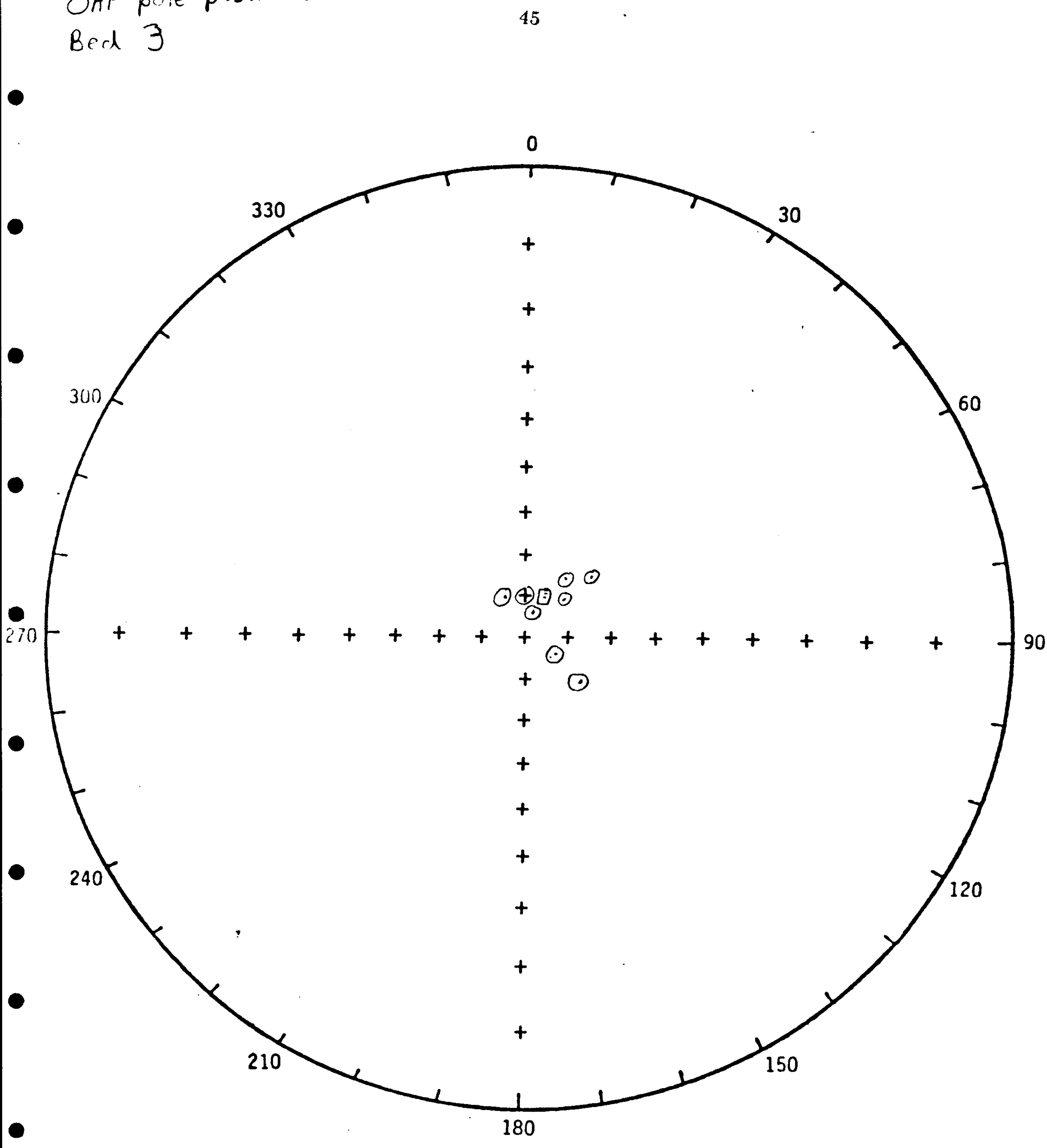


Figure 7.303
OAF pole positions
Bed 3



### 7.3. Results of ARM Trends

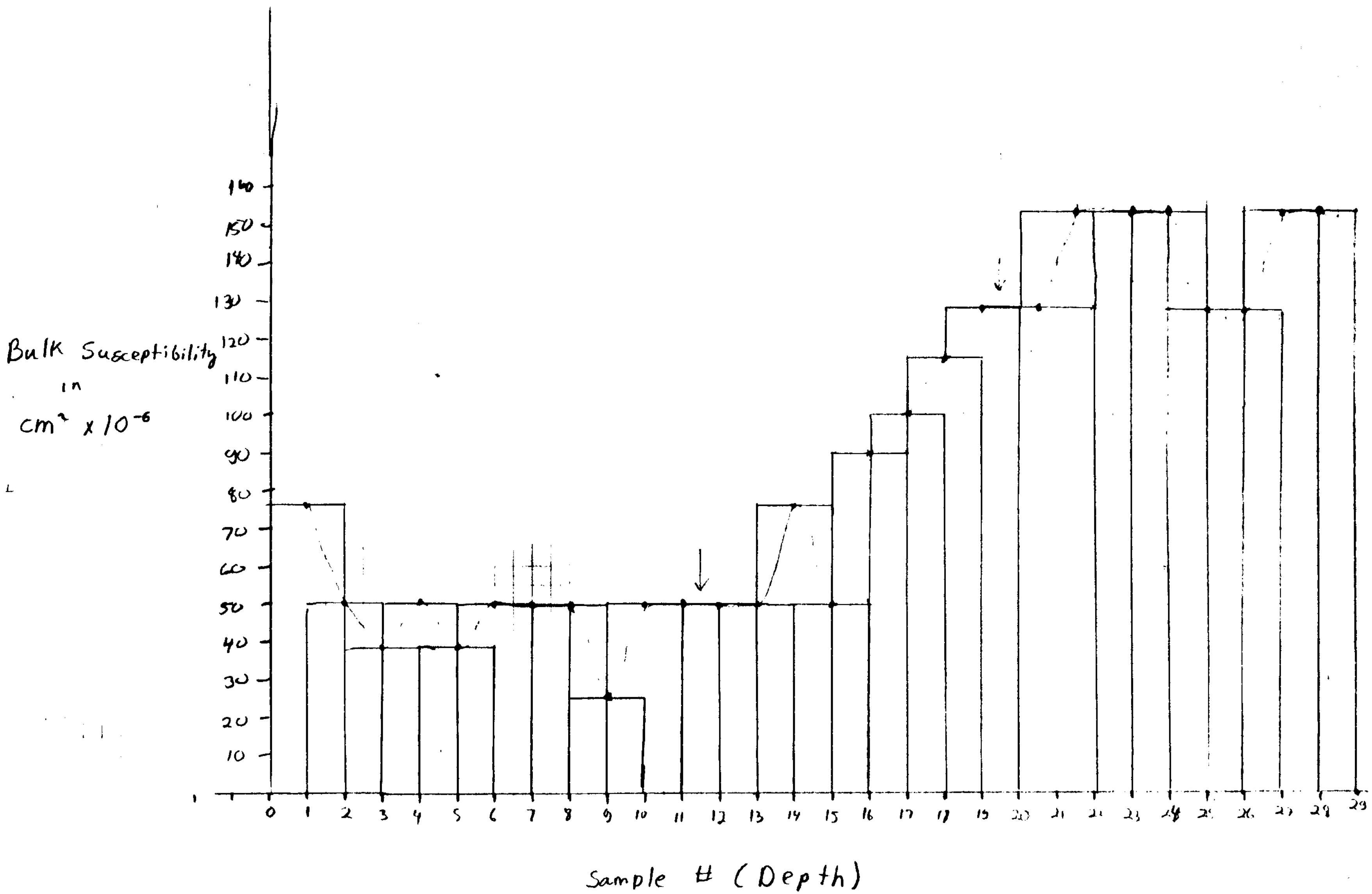
The graphs found in appendix 2 show the ARM decay curves for each core. All of the graphs show a relatively constant decay curve over the entire demagnetization process. This trend indicates that the magnetic moments seen in these decay curves are free of any viscious trends. The shapes of these curves are typical of magnetite grains [McElhinny]. This verifies my original assumption that magnetite was the main grain type contributing to the whole-core magnetism. The consistancy of the median destructive field (MDF) indicates that grain size remains constant throughout the sampling interval. This means that any change in the susceptibility of the cores would indicate a change in the amount of magnetite grains within a core. The small and constant grain size of these particles may indicate grains of organic origin, and not of clastic origin as originally thought.

### 7.4. Bulk Susceptibility Trends

The results of the bulk susceptibility readings can be seen on graph 7.4; they show three distinctive trends. Cores 0-12 show a very steady level of susceptibility at about 50*10-6 cm2. This zone of weak susceptibility followed by a transitionary zone (cores 13-19). At the highest level, cores 20-29, again show a constant susceptibility, but three times the strength of the lowest samples. As indicated earlier, this shows that there was greater concentration of magnetite in the upper parts of the lake deposit. Note that this also supports separations made earlier, solely on the basis of outward lithology.

Figure 7.4

Bulk Susceptibility vs
Sample Number

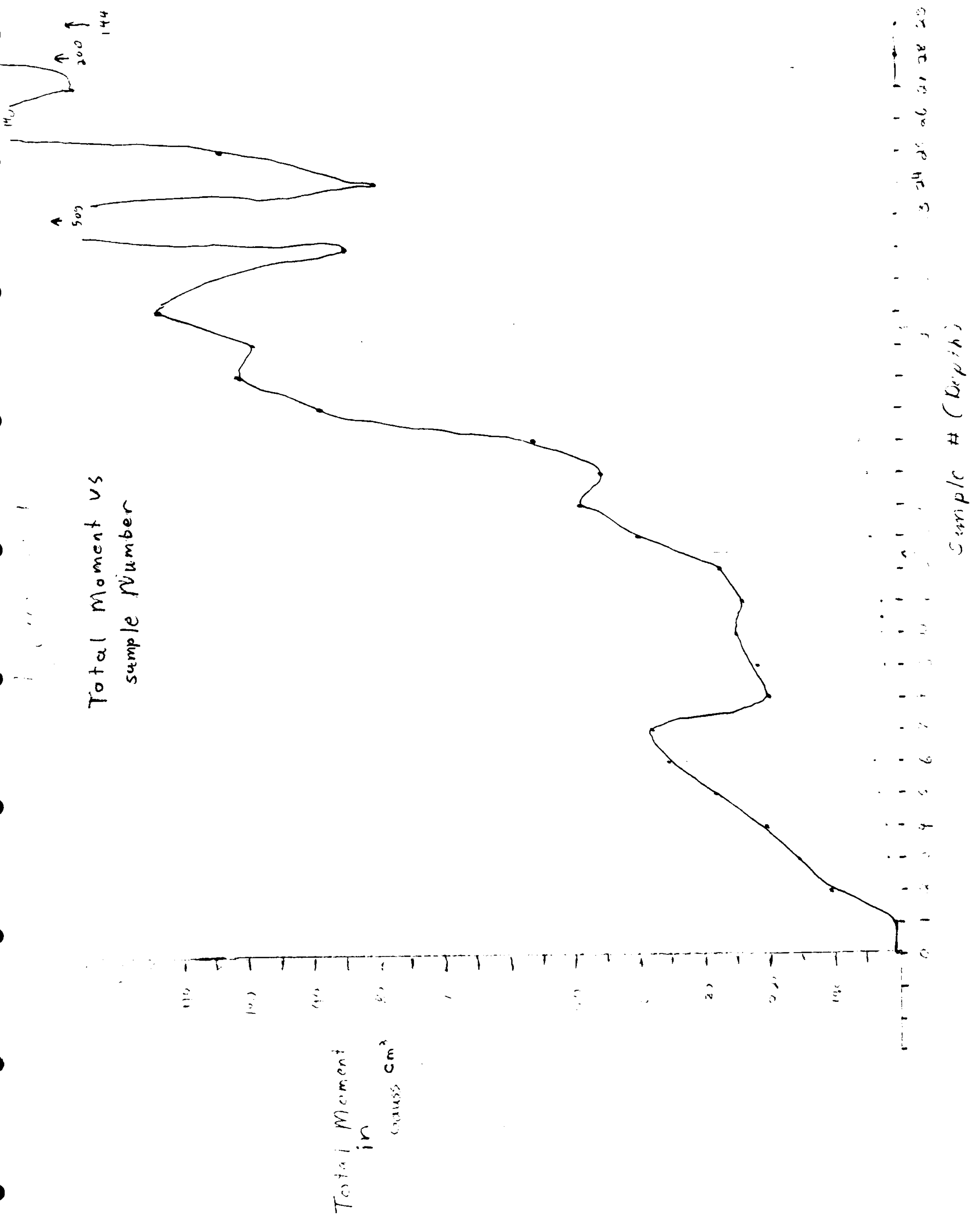


## 7.5. Other Overall Trends

Several other overall trends were plotted by core number (depth) these include the total magnetic moment (J0), the median destructive field (MDF), the optimium alternating field (OAF), inclination, and declination. The results and usefulness of each will be discused in the following section.

### *7.5.1. Total Magnetic Moment J0*

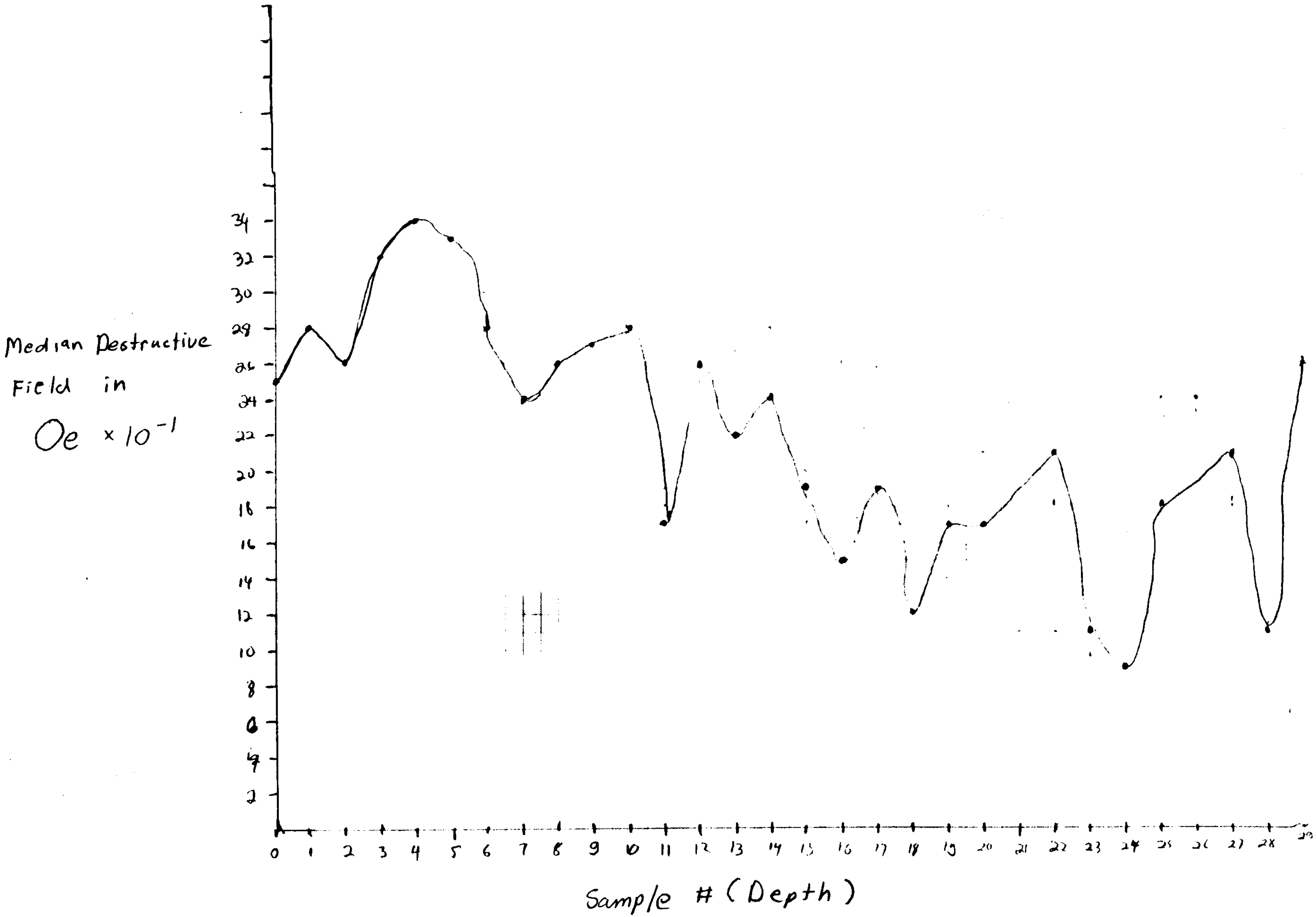
In figure 7.5.1 the total magnetic moment is plotted against the sample number. The overall moment is dependent on two factors: the bulk suseptibility, and the strength of the original remanent magnetism. The values of J0 seem to be easily separated into the three groups based on lithology, as discussed earlier. This again verifies that there is considerable variation of magnetic intensity in the various lithological layers.


Total Moment vs sample Number
Sample # (Depth)
Total Moment in Gauss cm³
500
200
144

*7.5.2. Median Destructive Field MDF*

In figure 7.5.2 the median destructive moment is plotted against the sample number MDF is often used as a general measure of change in grain size, but in these samples it was of little use. There is much erratic behavior of MDF over the entire length of the sampled section. Even though there is a slight over-all decreasing trend in the results of the MDF of the ARM results have already shown that there is little variation in grain size after cleaning. Therefore, this change must be due a viscous moment.

Figure 7.5.2
Median Destructive Field
vs Sample Number

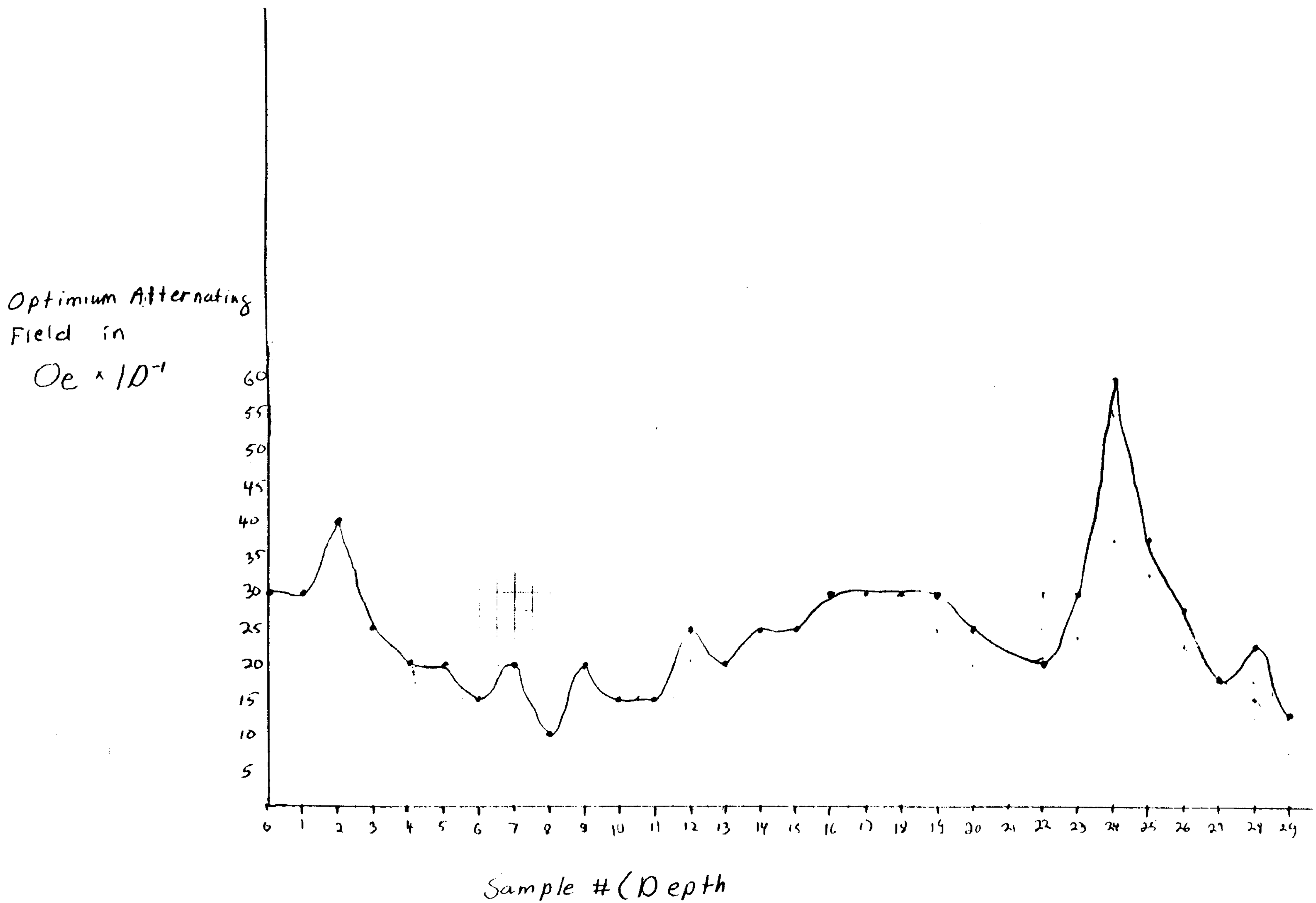


### *7.5.3. OAF Values*

In figure 7.5.3 the optimium alternating field is plotted against the sample number This plot was made solely to see if there is any correlation between the OAF results and the external lithology. There were too many variables that could affect these values, and no clear trends were evident.

Figure 7.5.3

Optimum Alternating Field vs Sample Number



### *7.5.4. Inclination and Declination*

In figures 7.5.4 and 7.5.5 one can see the changes in OAF values for incination and declination values with depth. Both show wild variations in the lowest section of the sample. This is believed to be due to the magnetic event that was happening at the time of the original deposition. Otherwise, the graphs show very little variation as the pole position became more constant in the latter history of the lake.

Figure 7.5.4

The Declination of the sample at Optimium Field vs Sample Number

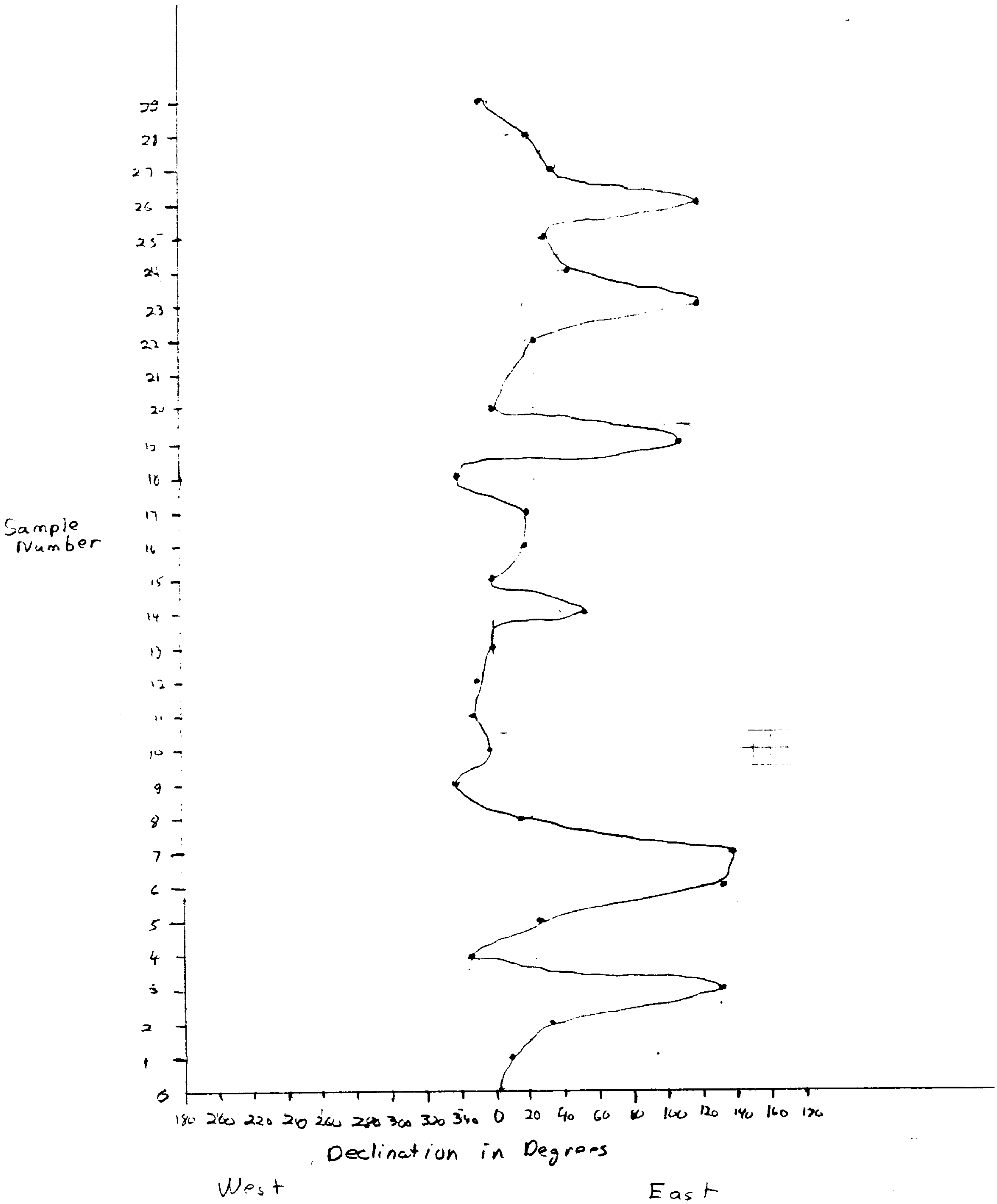
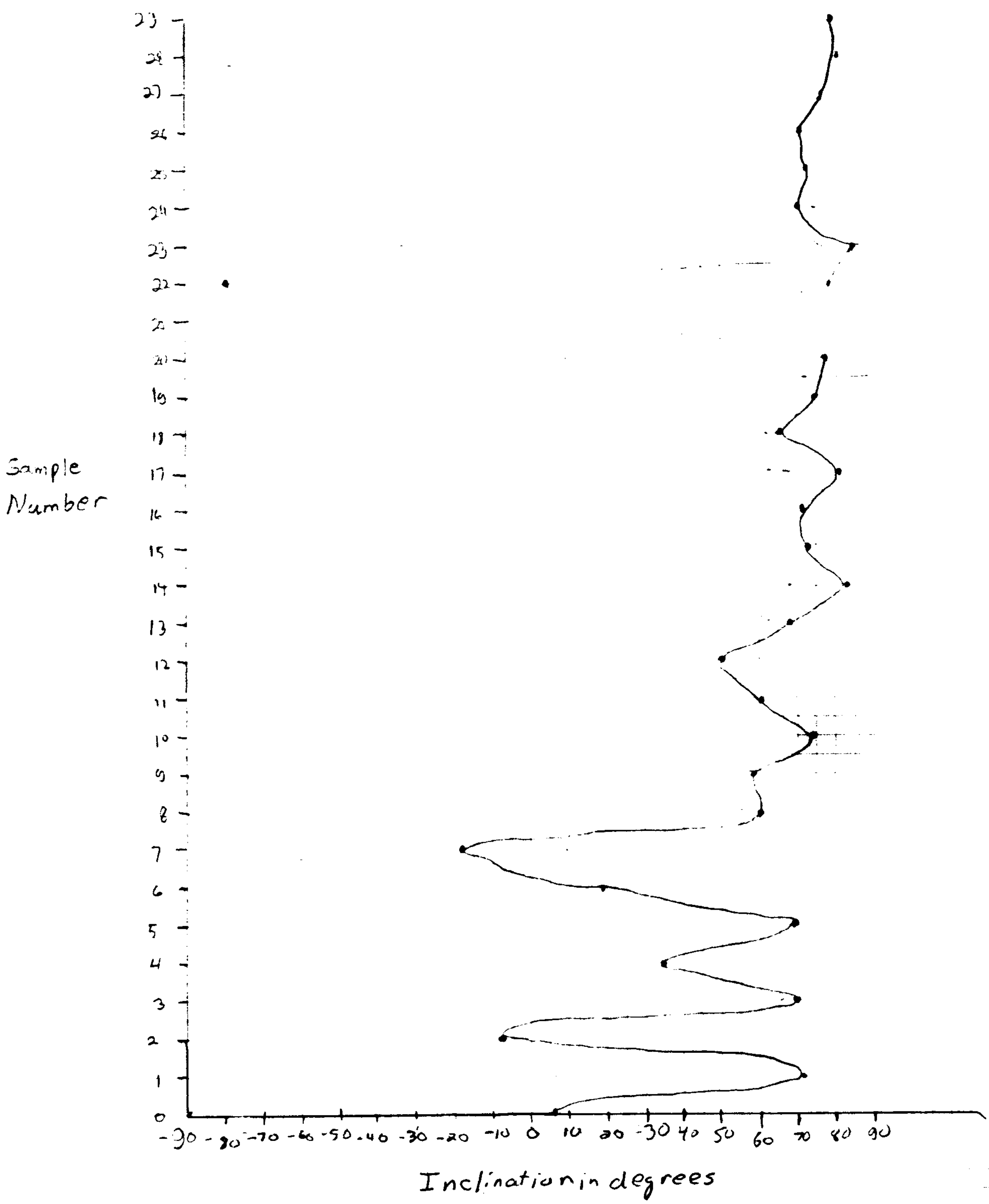


Figure 7.5.4

The Inclination of the Sample at Optimium Field vs Sample Number.



# 8. Conclusion

As stated at the beginning of this geophysical research report, the purpose of this investigation was to determine if the magnetic properties of lake sediments could be used to gain useful geological information. By using only three physical methods to obtain my data, A. F. demagnetization, bulk susceptibility, and anhystric remanent magnetization, I have been able to successfully gather otherwise unobtainable geologic information. These findings can broken down into four major categories.

## 8.1. Lithology and Magnetic Properties

There are three visibly different layers of material found in the area of sampling: the bottom most being mottled grey and brown, the middle being an organic black clay, and the top most being a silty brown clay. Though these layers can sometimes be hardly differentiated by direct observation, they show up quite clearly after magnetic testing. Each layer has its own distinctive magnetic fingerprint given to it by its magnetic grains. The bottom layer showed a very low magnetic moment and a relatively weak magnetic susceptibility. These properities also manifested themselves in less stable pole positions, as in cores 001 and 002. The middle black layer showed very stable pole positions and transitionary levels of susceptibility and total magnetic moment. The top brown layer showed very stable pole positions similar to the previous layer, but it had the maximium of susceptibility and total magnetic moment. The magnetic fingerprinting of various layers could be used in the future to distinguish layers not easily differentiated by the human eye. These findings could be used in future lake studies as a ready means of classification.

## 8.2. Depositional Mechanisms and Source

The various magnetic properties that were discernable could also be used to derive some estimation of the depositional mechanisms and the soürce of the lake water. As mentioned in the chapter on the background geology, there two possible sources of the magnetic grains mentioned in the local literature. The first was the run off from the nearby glaciers. If this had been the case, there should have been a dominant rythmic layering and variety of magnetic minerals found like those samples taken from the Minford Silts in northern Kentucky in Bonnet. However, this was not the case. The other possibility is that the magnetite was derived from the local country rock (Blackhand Sandstone). But the grain size of magnetite particles in the Blackhand varies greatly and, in general, they are very large. In my lacustrine samples, all the magnetic particles are in the clay-size range and show little size variation, as seen from the ARM study. I believe the answer lies in the increased deposition of magnetite in the upper two organically dominated layers. This is the opposite of any clastic depositionary trend. If one considers the possiblity of organically produced magnetite, as mentioned in Frankle, the magnetic behavior fits the depositional history much better. This conclusion also agree with the geochemical properties of magnetite that suggest that authigenic magnetite may produced in highly reducing conditions, like those that must have existed in the upper two layers of the lake sampling.

## 8.3. Dating by the Lake's Pole Position

The pole position of the upper two levels of the lake deposite indicate an average pole position of Latitude 62.87 and Longitude 72.45 degrees west. This pole position indicates an age some time in the Holocene but more then 5000 years ago. This is also consistent with the depth of the present paleo-soil, which is about two feet thick. From this it is safe to estimate that this lake survived well into the post-Wisconsian.

### 8.4. A Previously Unkown Geomagnetic Event

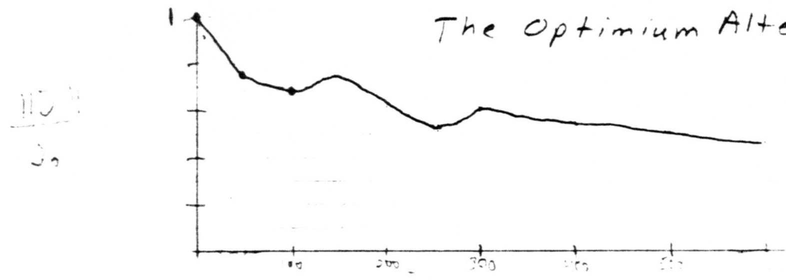
Of possibly the most interest was the unexpected discovery of a previously unknown magnetic event that occurred less then 8000 years ago. This magnetic event appears to match the present model of magnetic excursions or full reversals. This model purposes that there is an extreme decrease in the earth's magnetic field intensity and inclinations followed by a full polarity reversal or just a simple return to the previous field direction. If this, and other Pleistocene and Holocene paleomagnetic polarity anomalies detected earlier by other authors, are correct, the earth's magnetic field may be much more active during the past million years than previously thought.

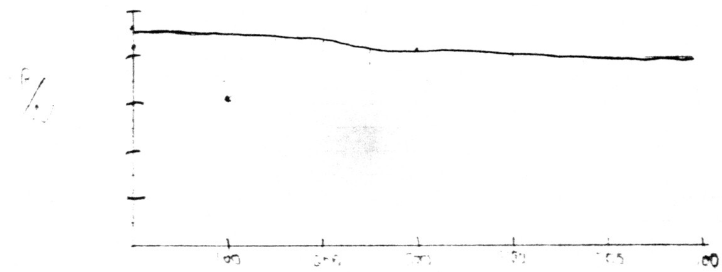
I believe the results from my study support further research into the magnetic properties Pleistocene and Holocene of lake sediments.

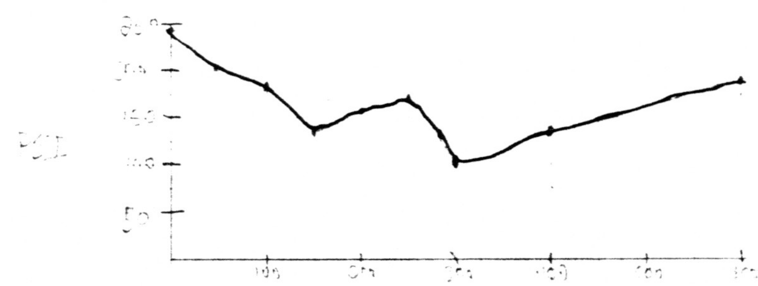
# I. Graphs of OAF Results

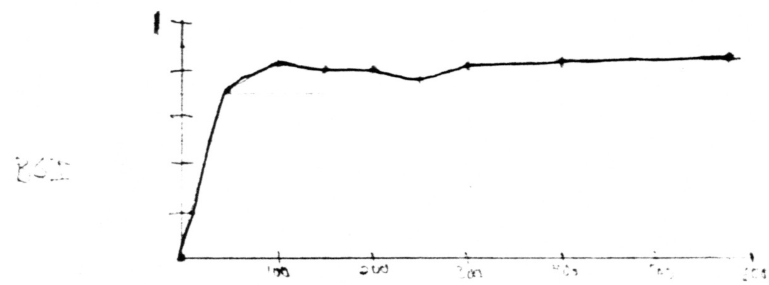
CORE HAA-009

Plots used to derive
The Optimium Alternating Field









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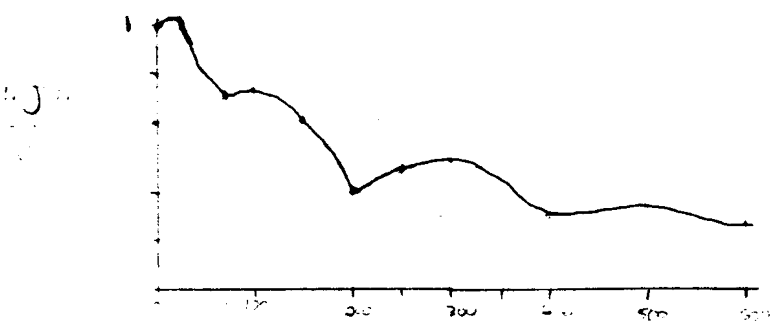


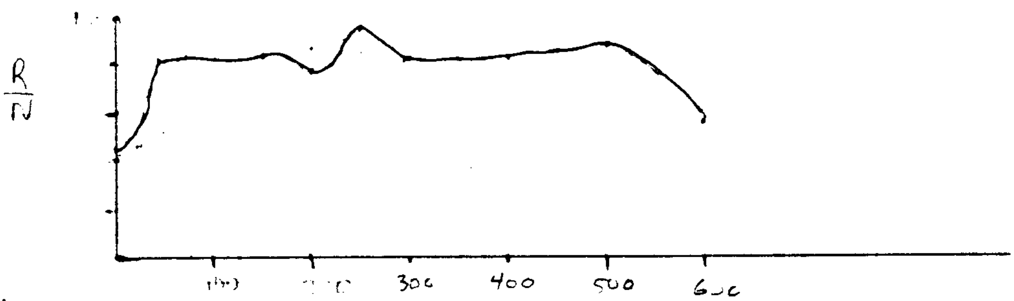


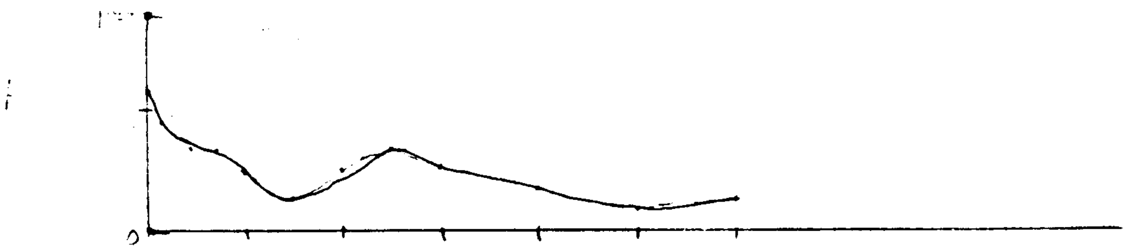


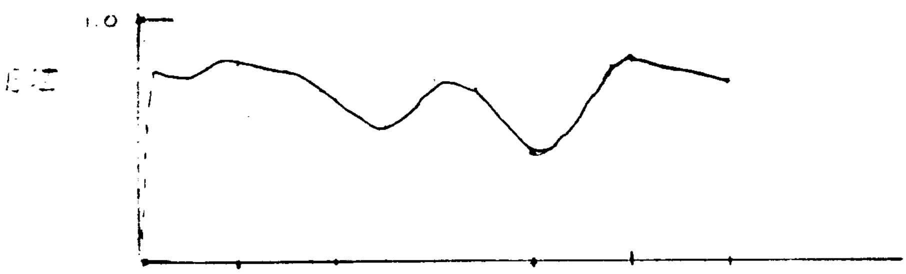

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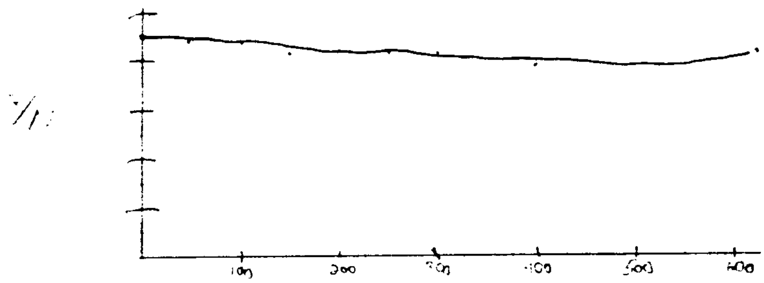

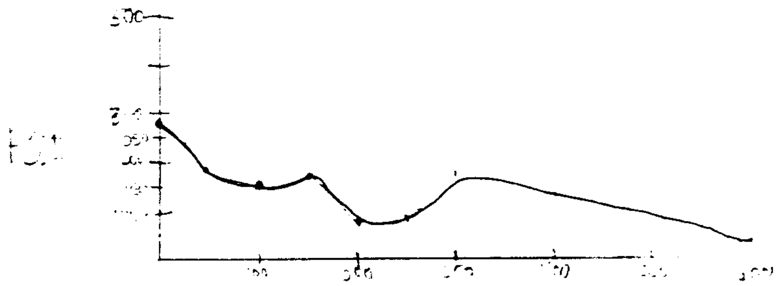

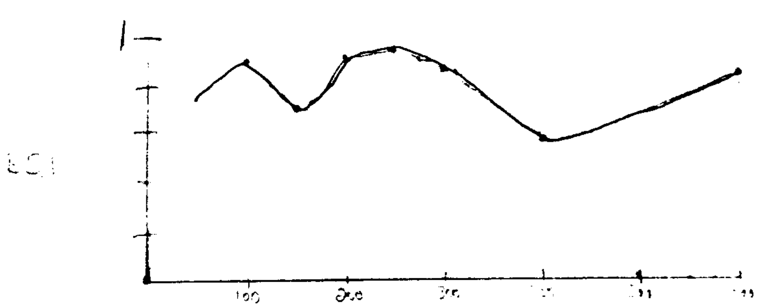

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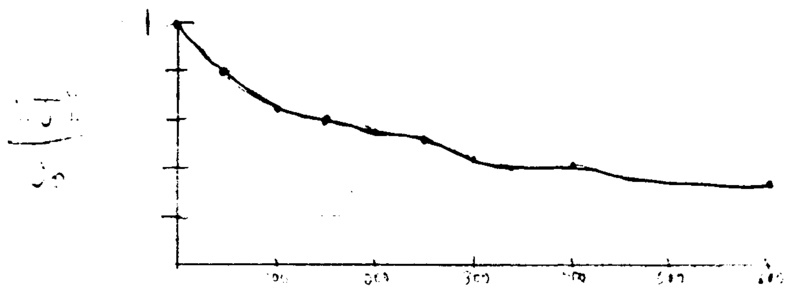
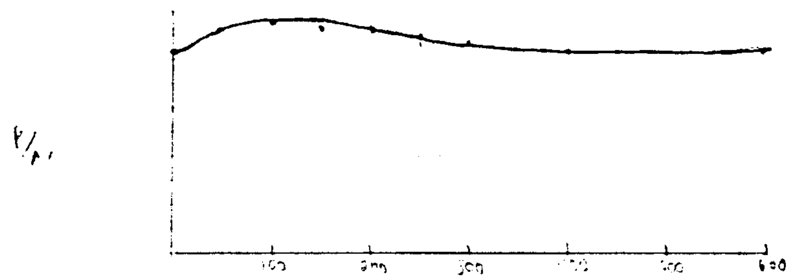
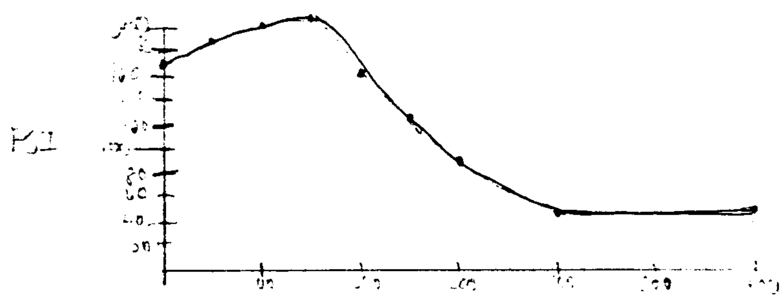
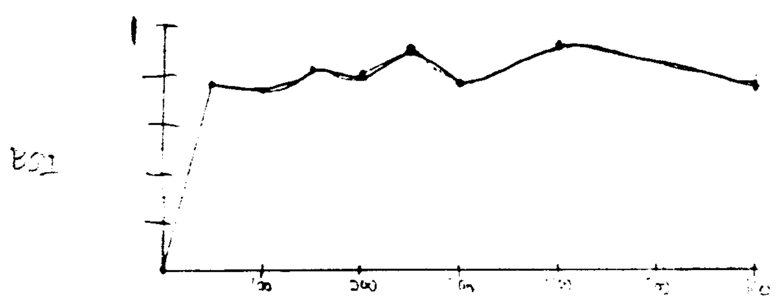
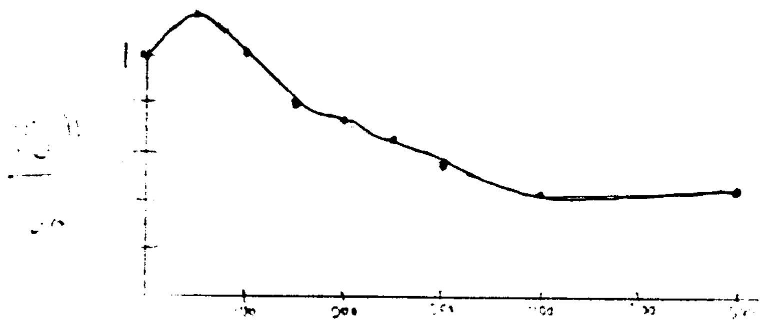


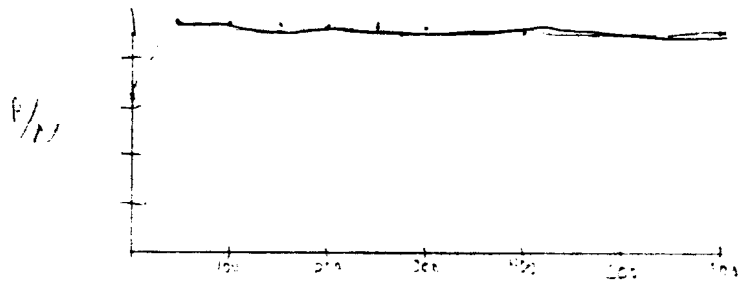


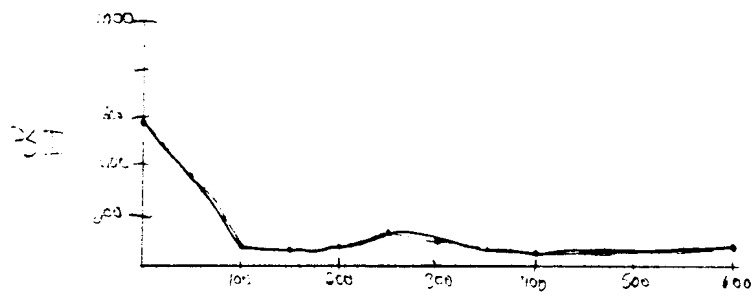


CORE - HAA - 007





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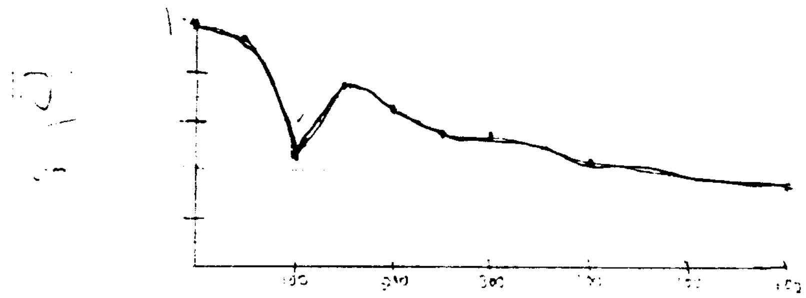

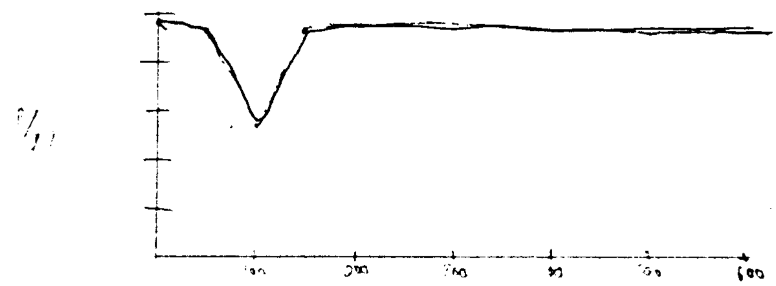

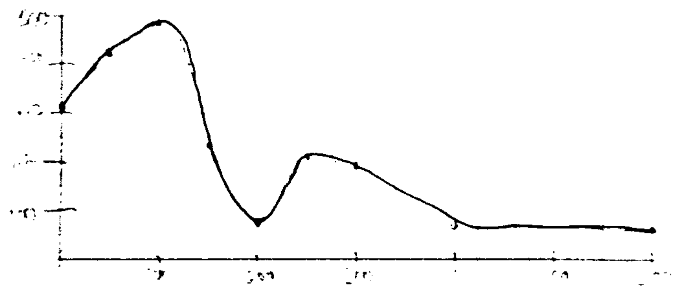


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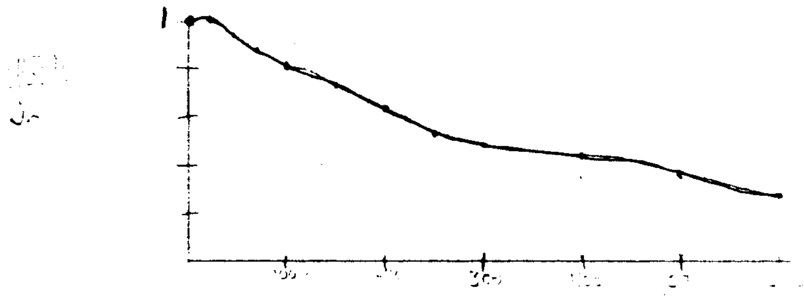


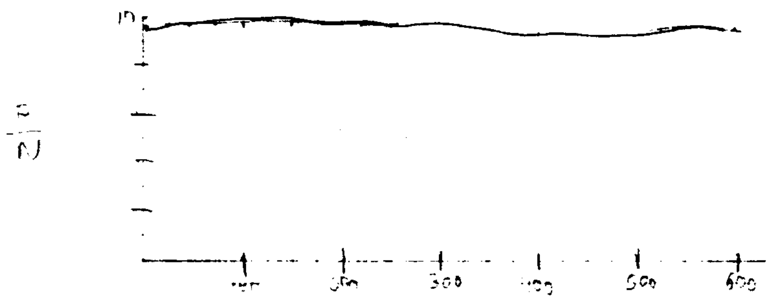


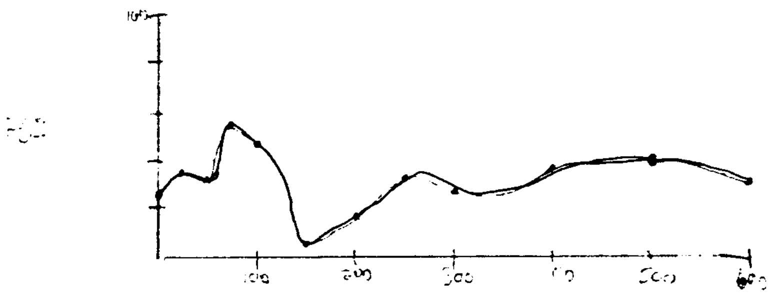


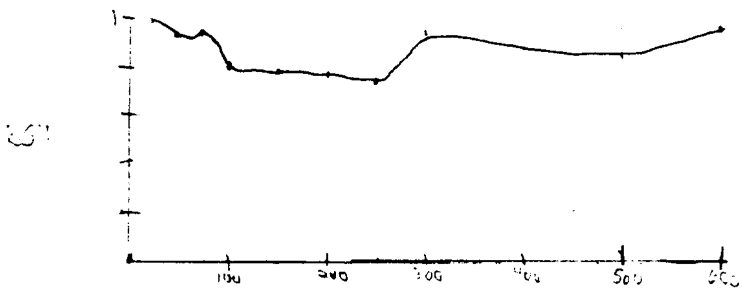

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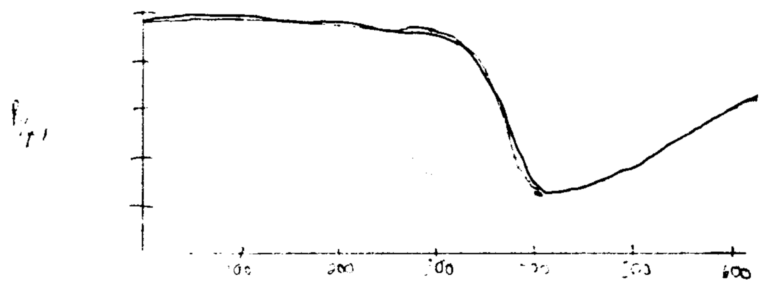

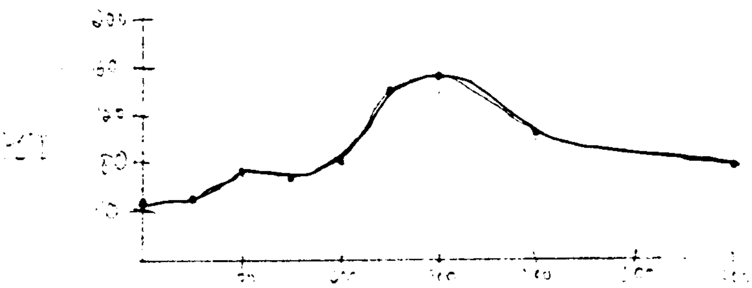

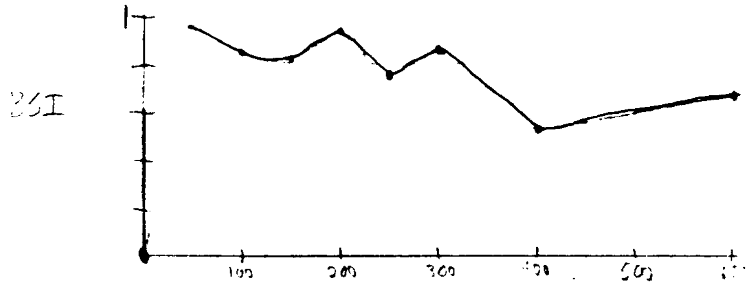

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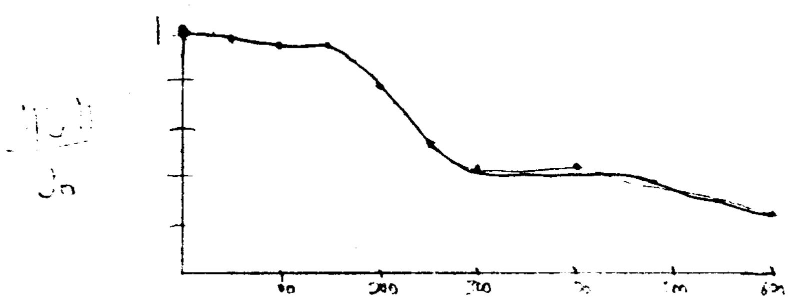

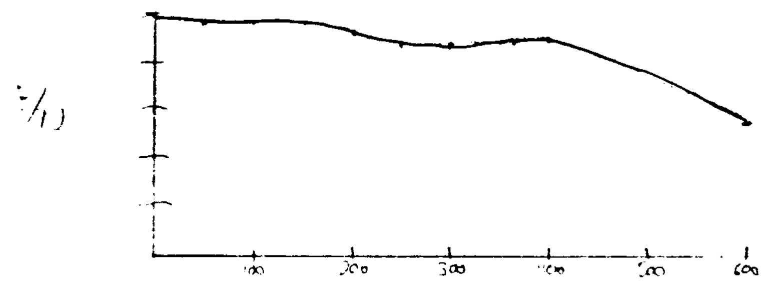


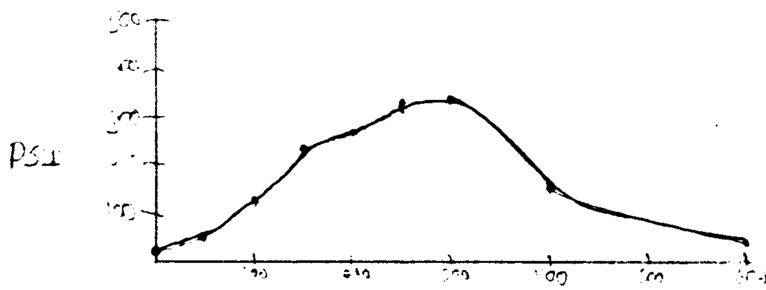


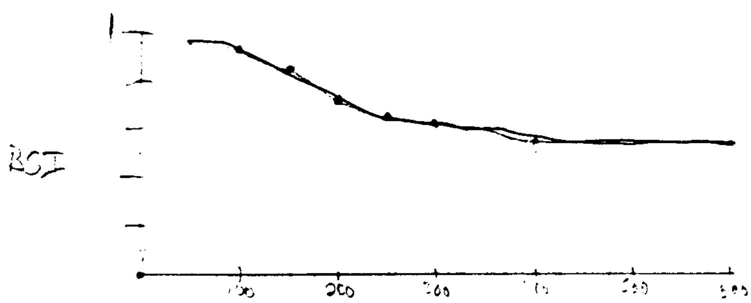

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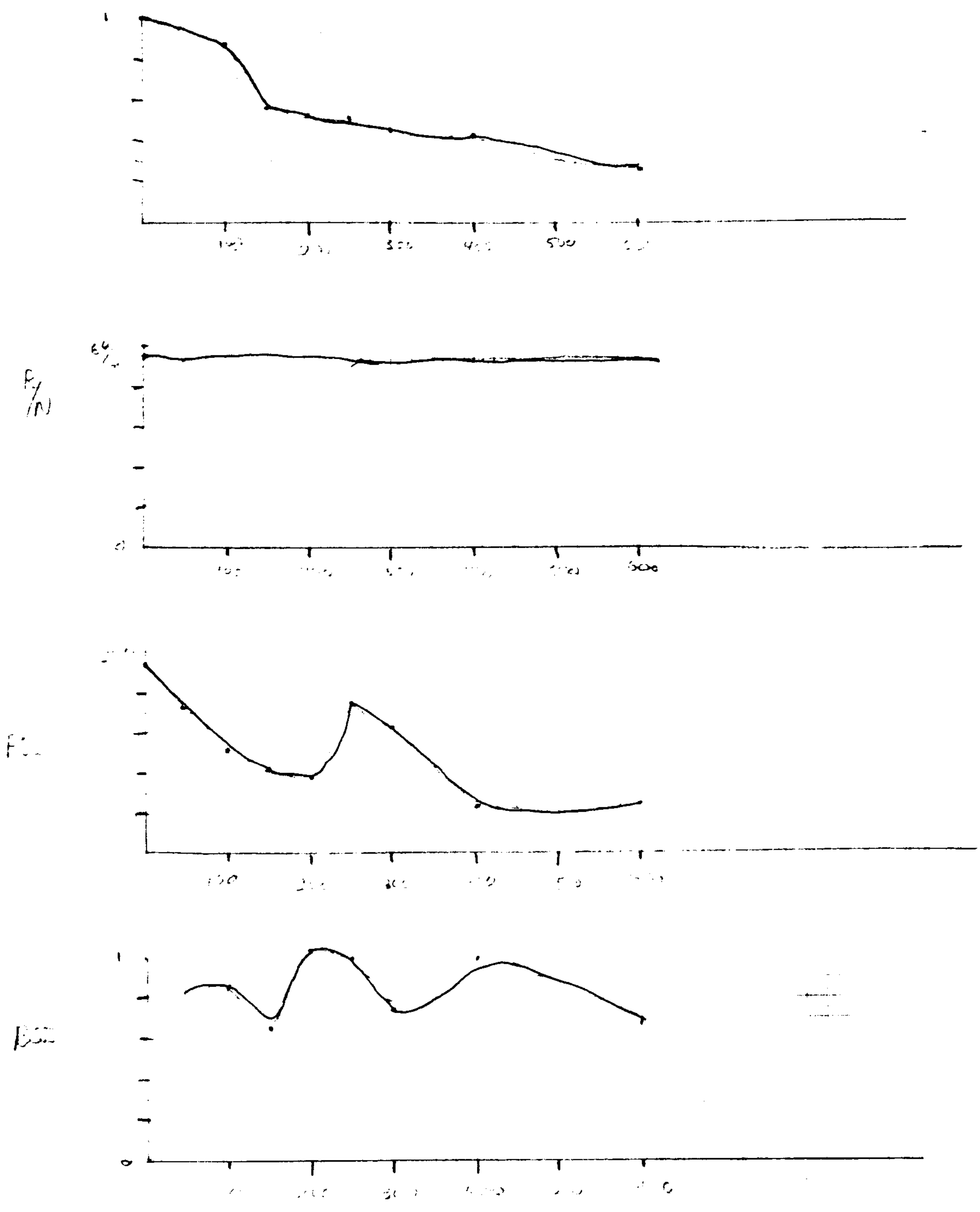

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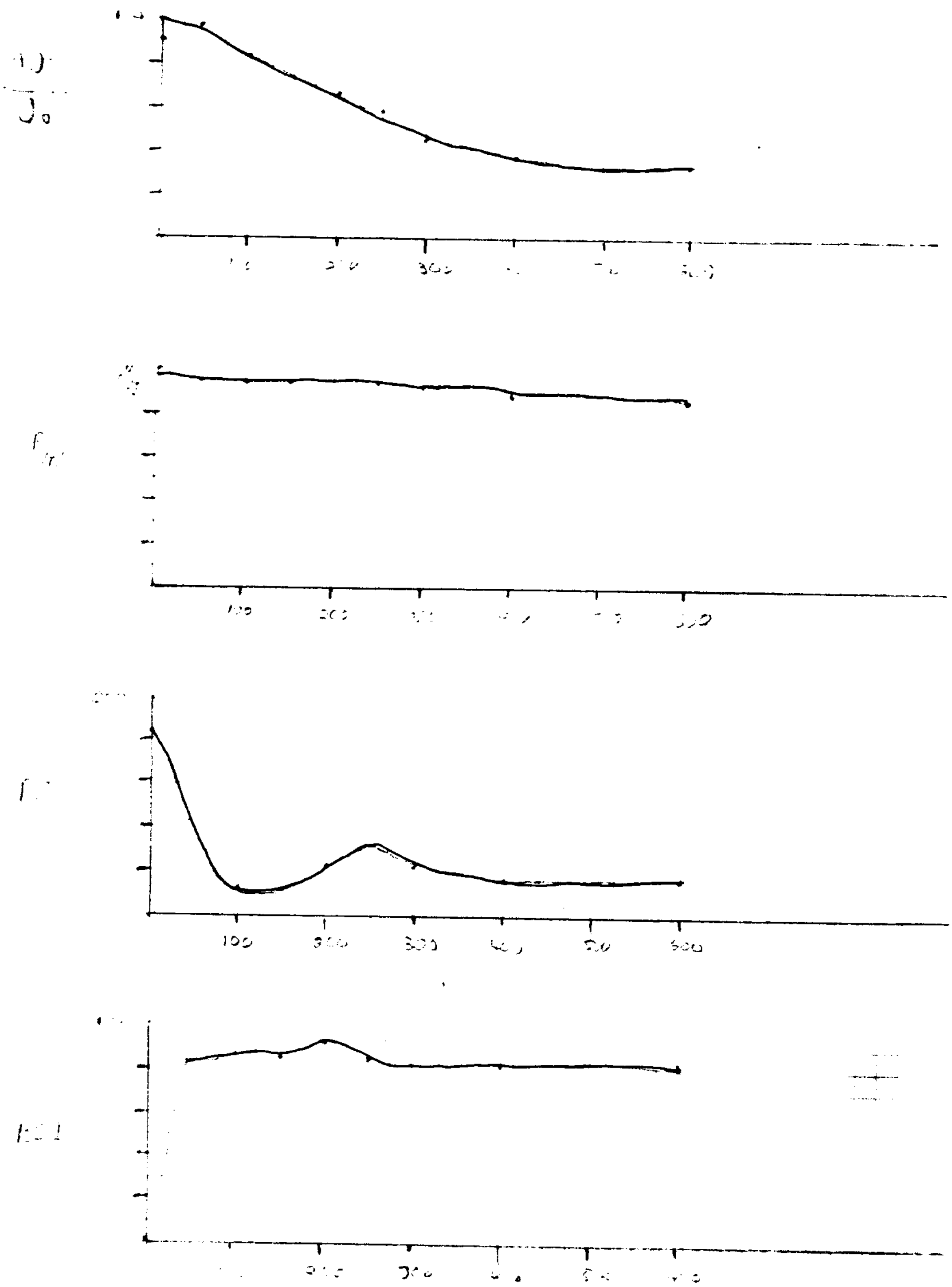

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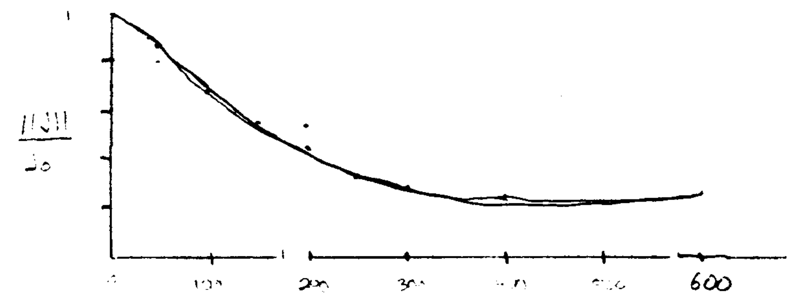

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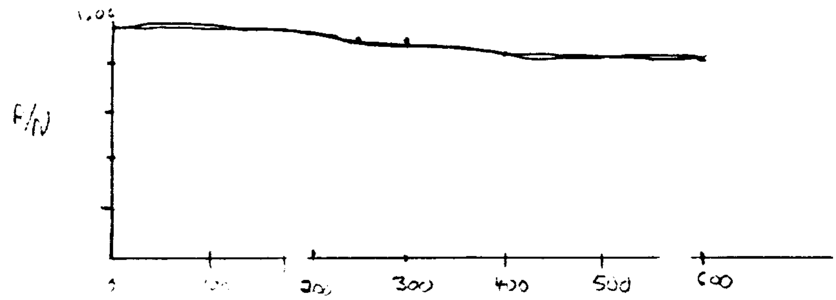

F/N
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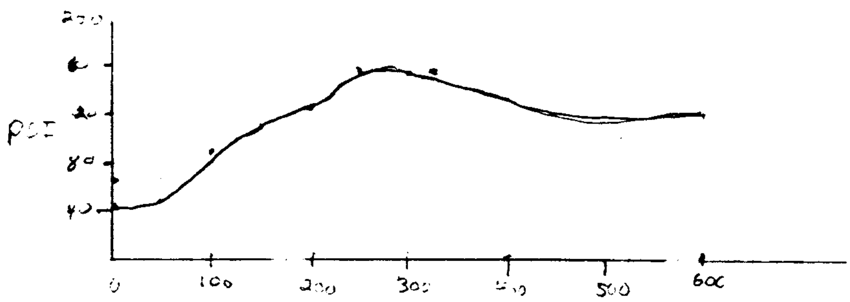

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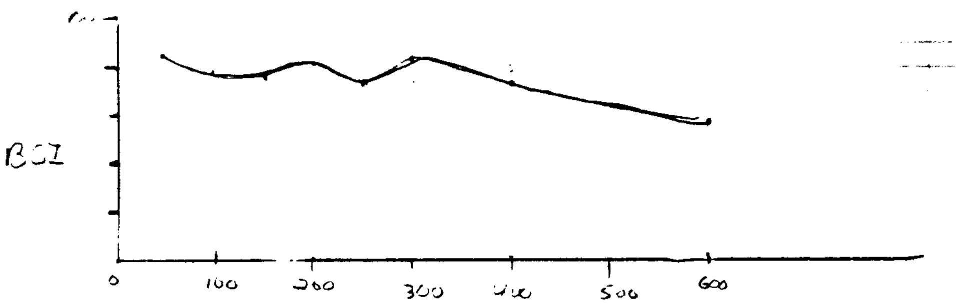

BSI
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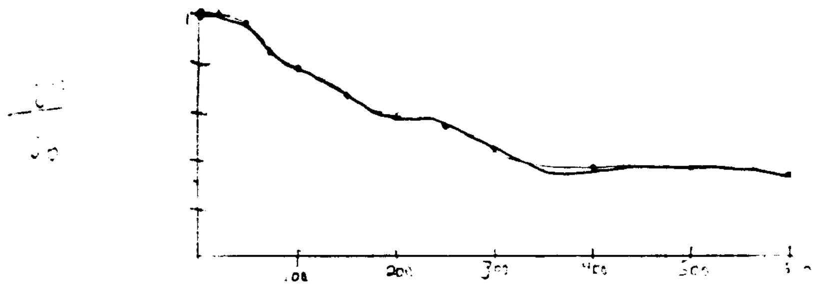
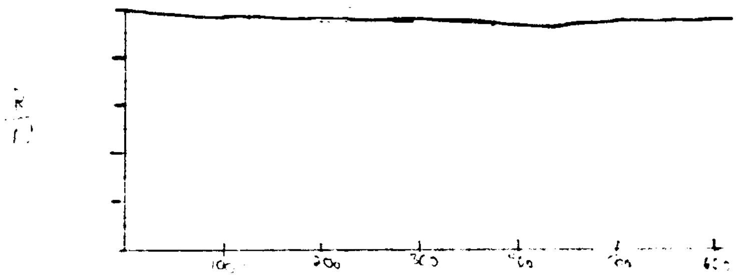
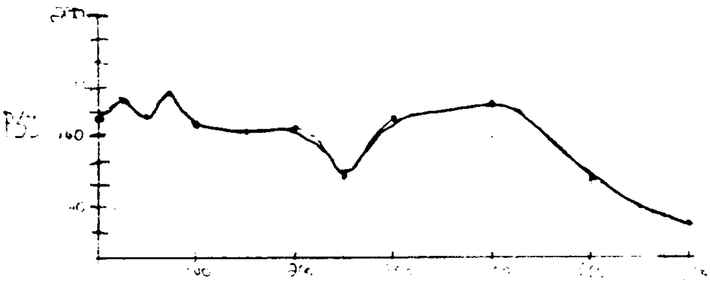
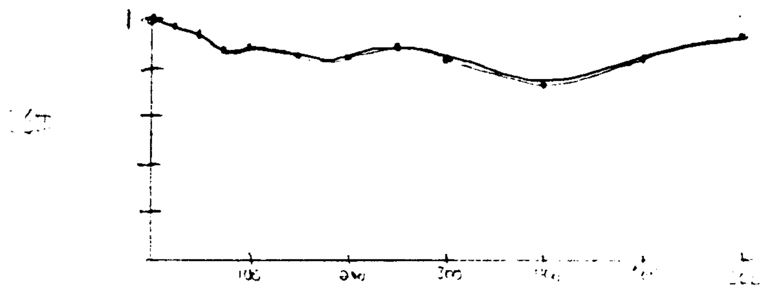
500
600

CORE HAA-013



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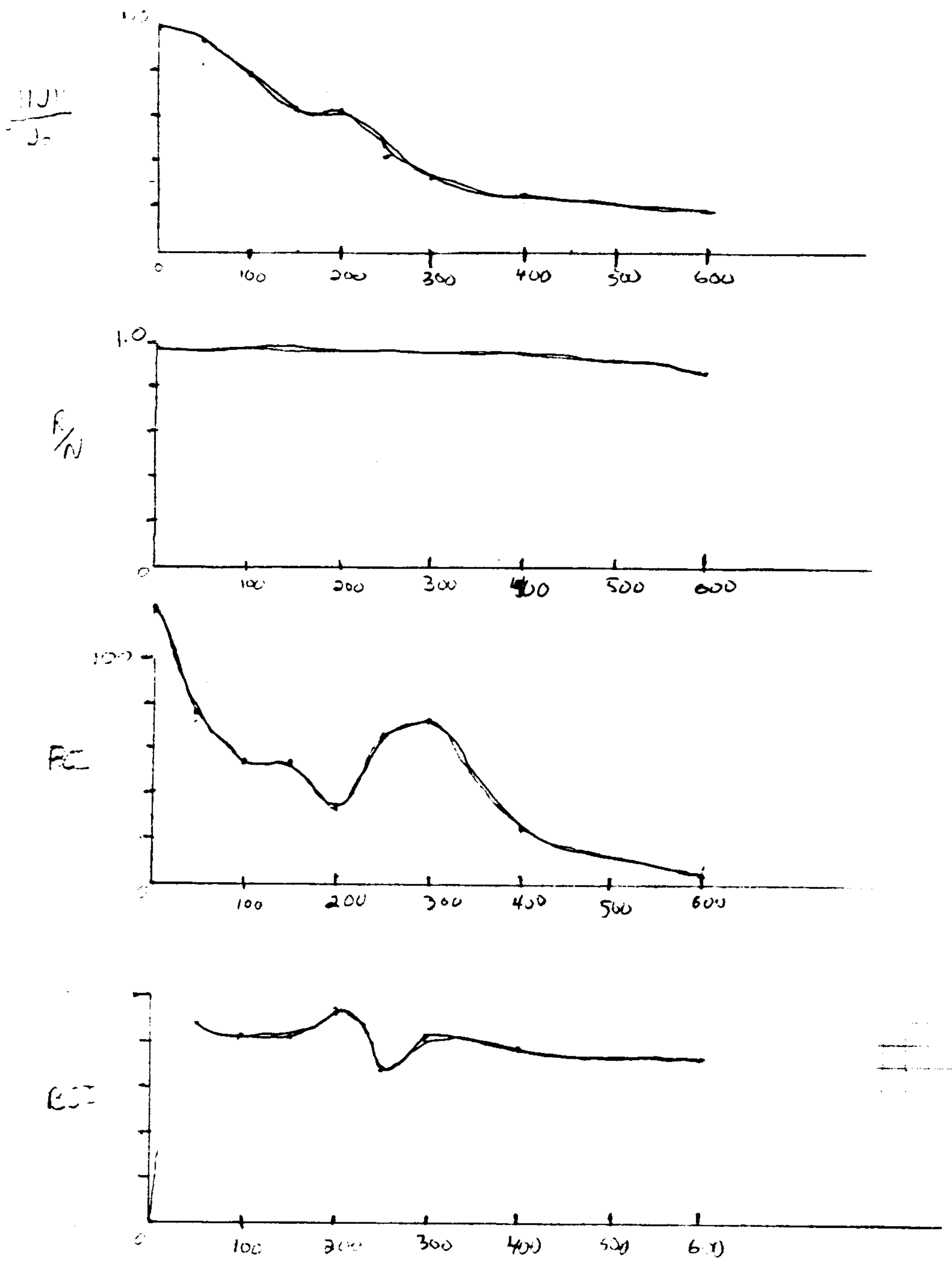

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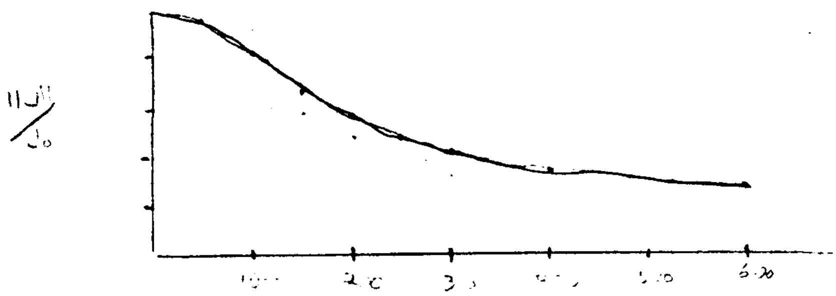

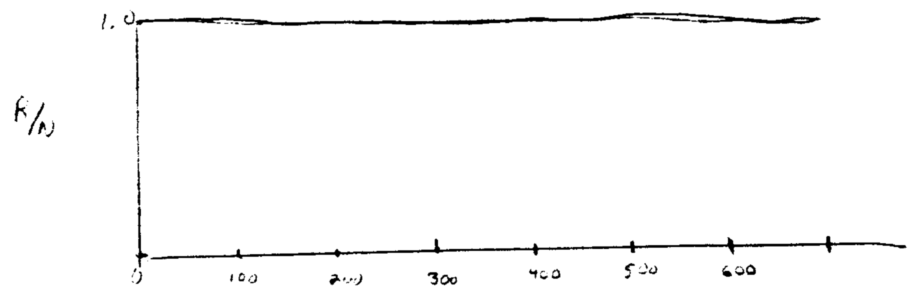
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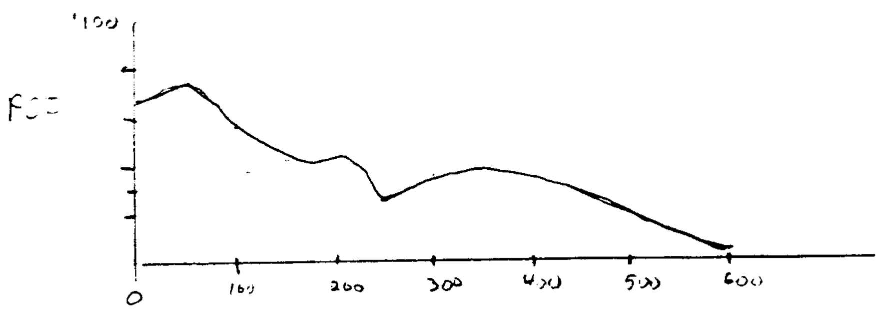
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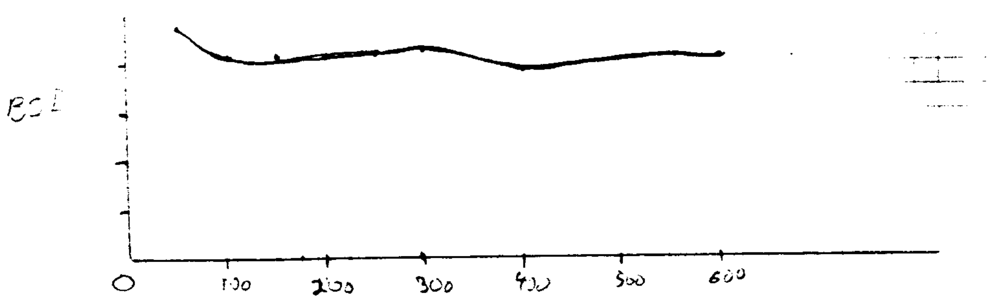
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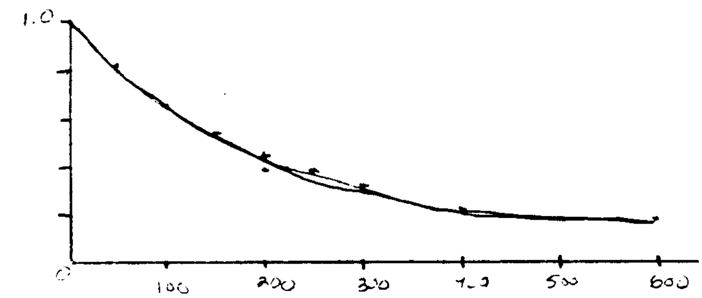

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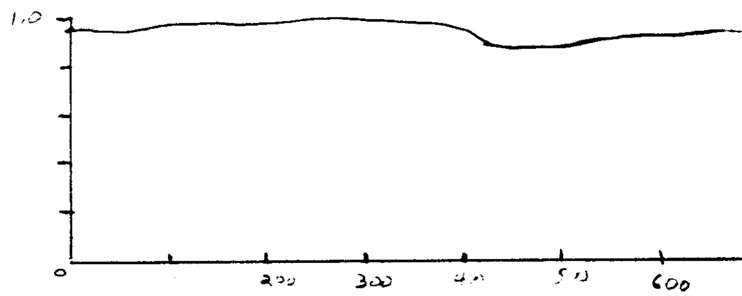

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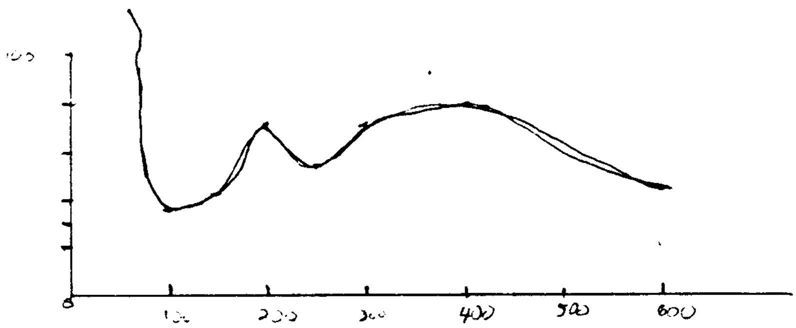

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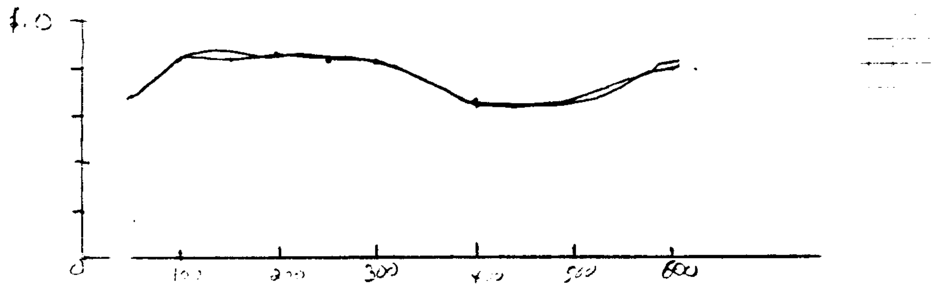

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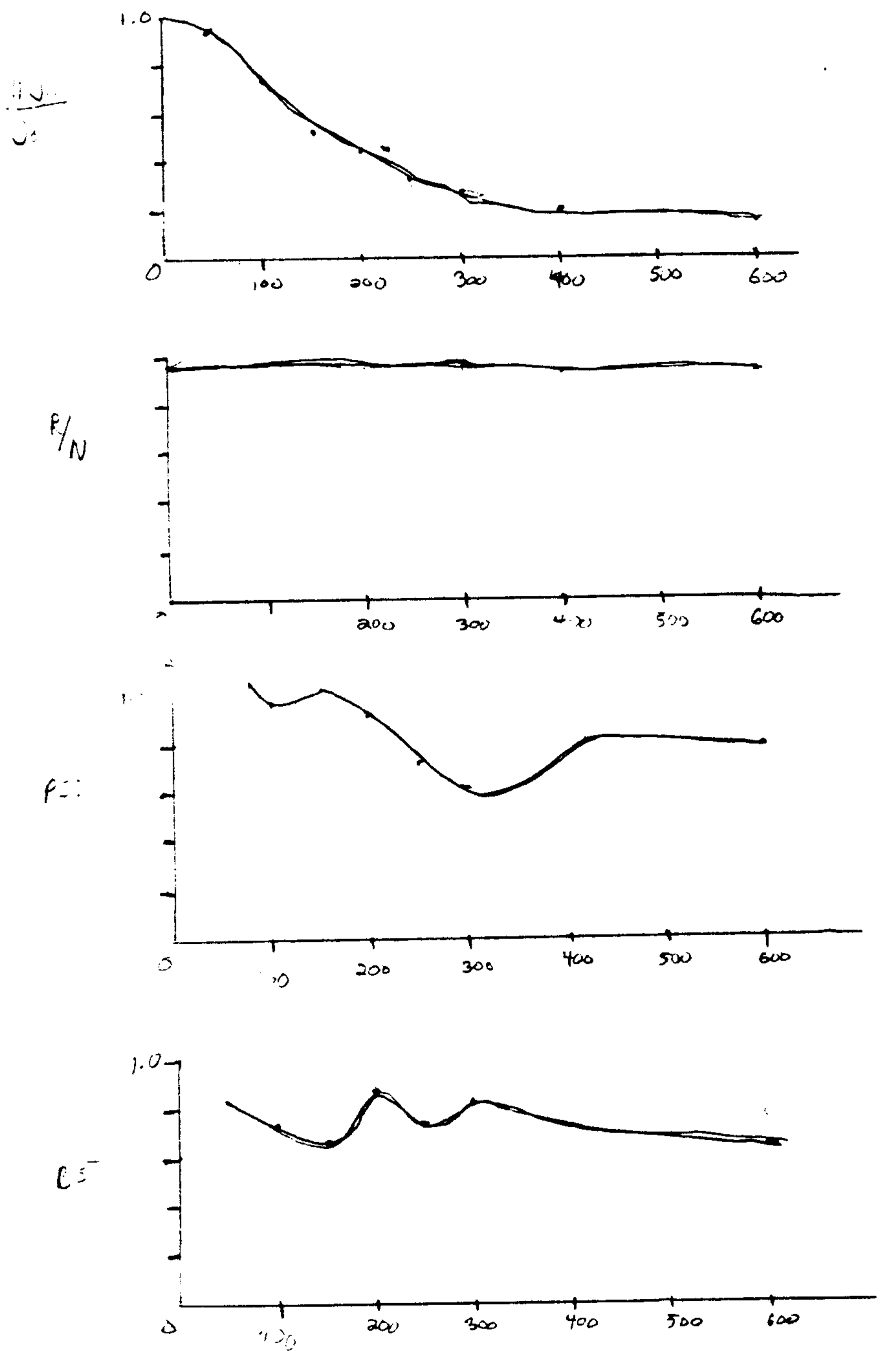
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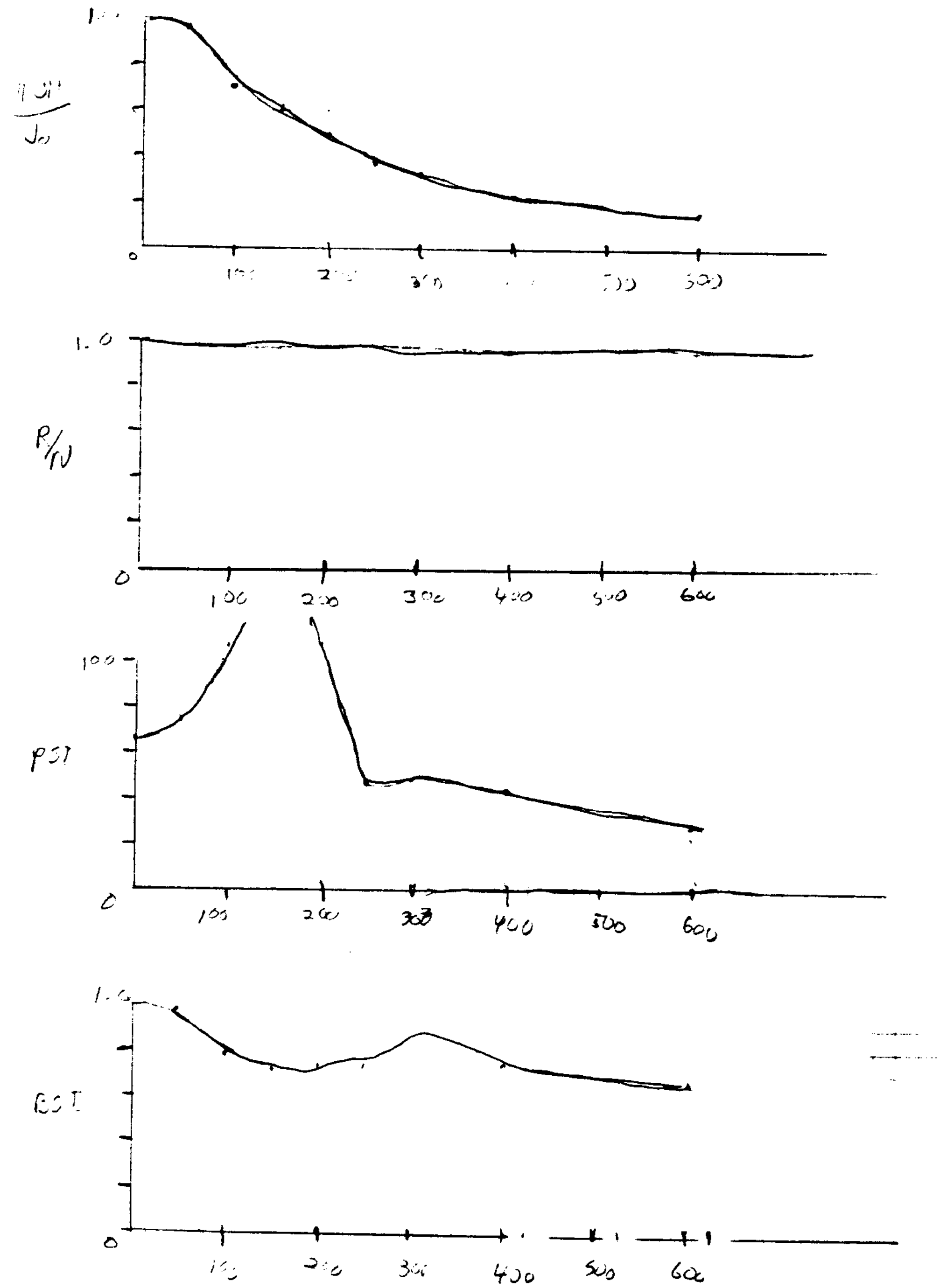
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BSI

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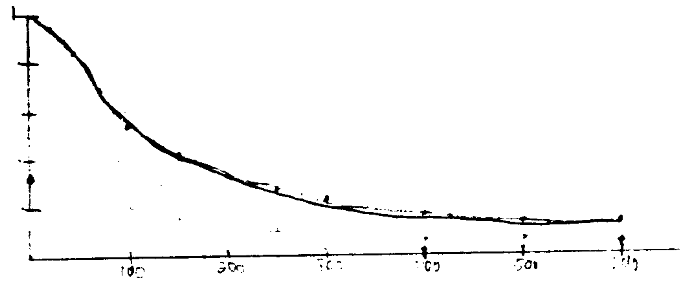


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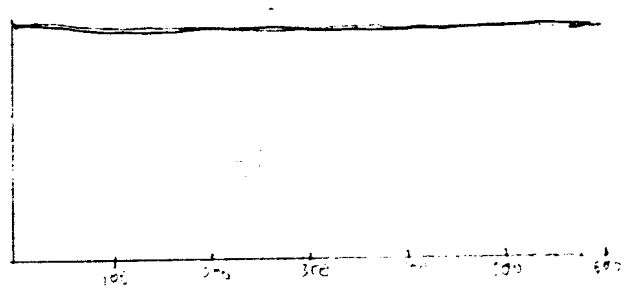


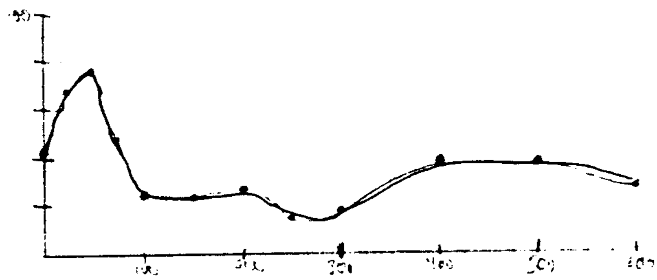


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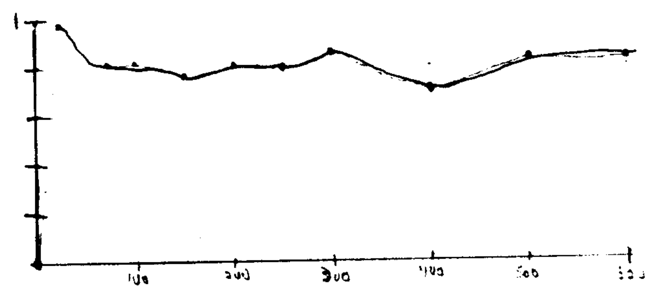

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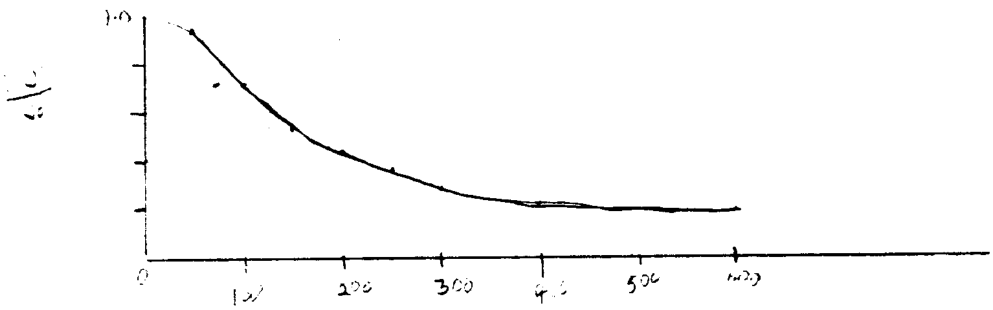


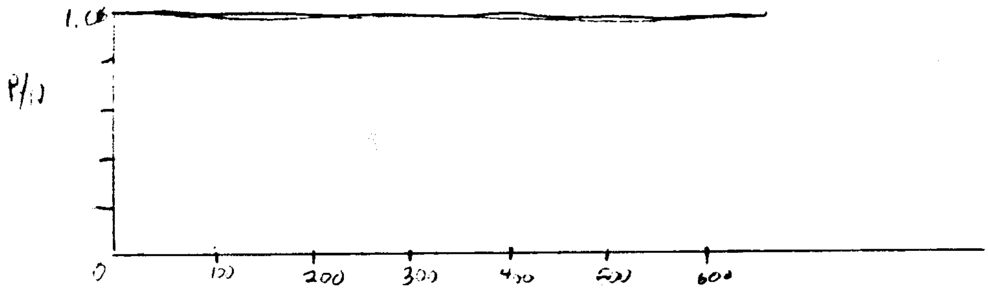


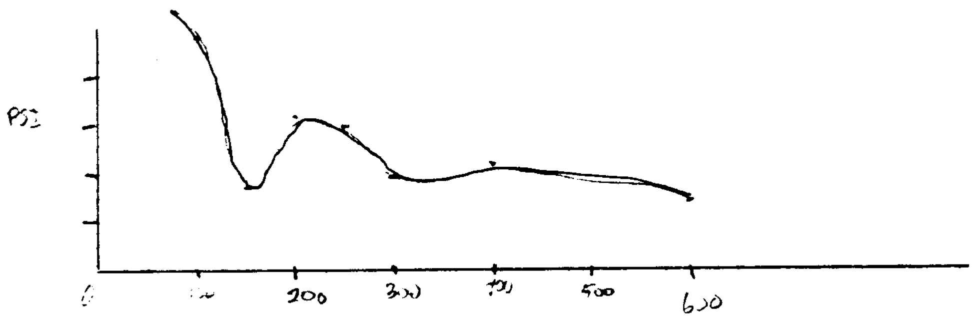


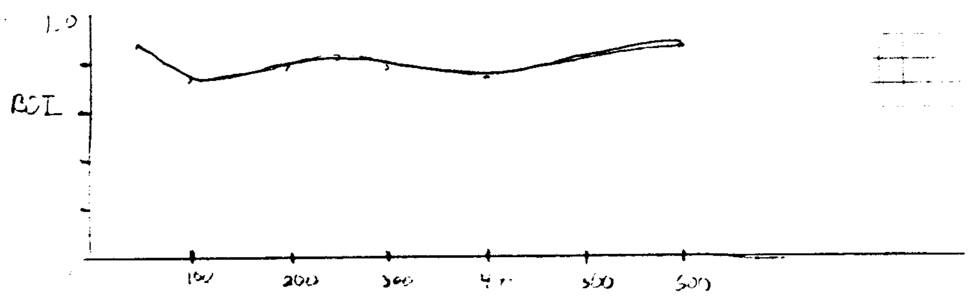

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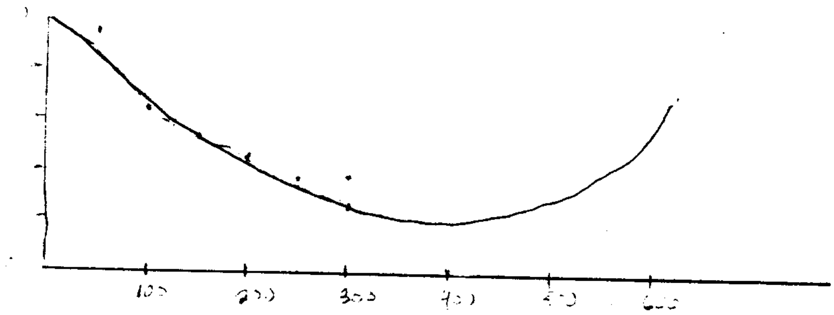


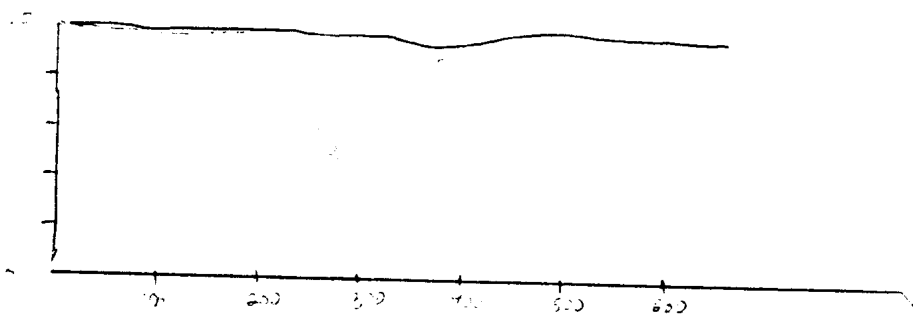

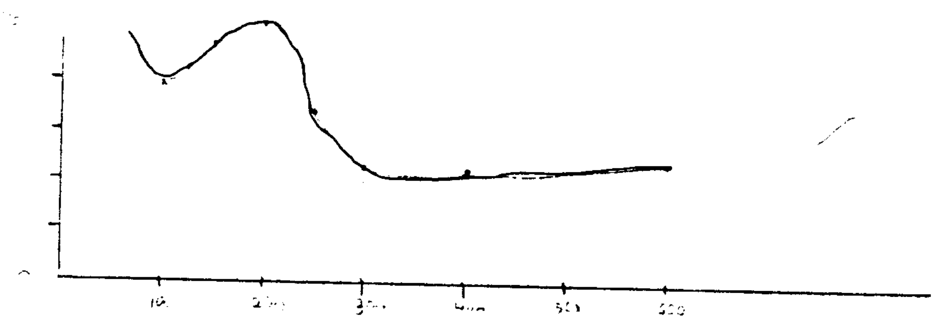

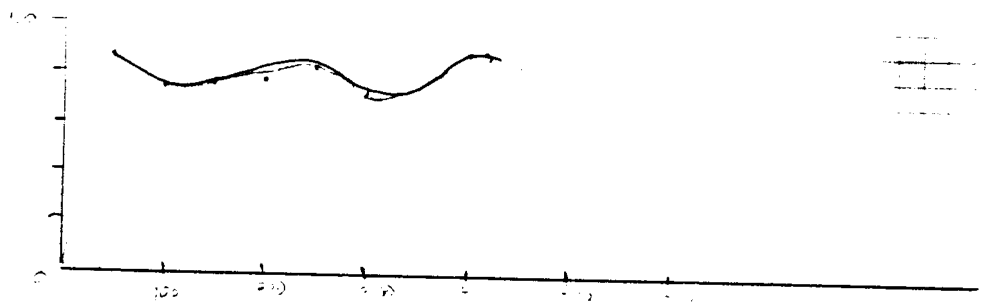

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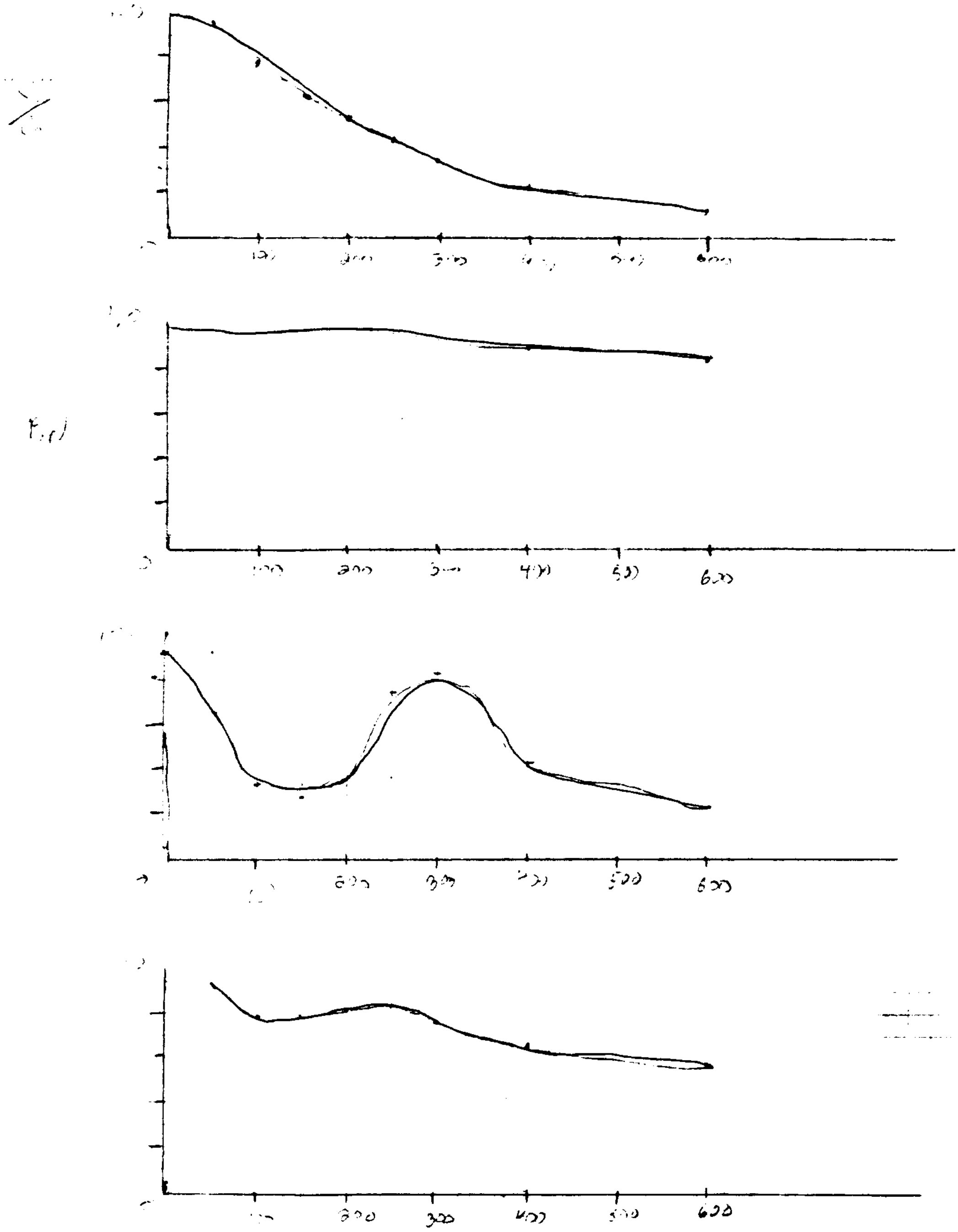

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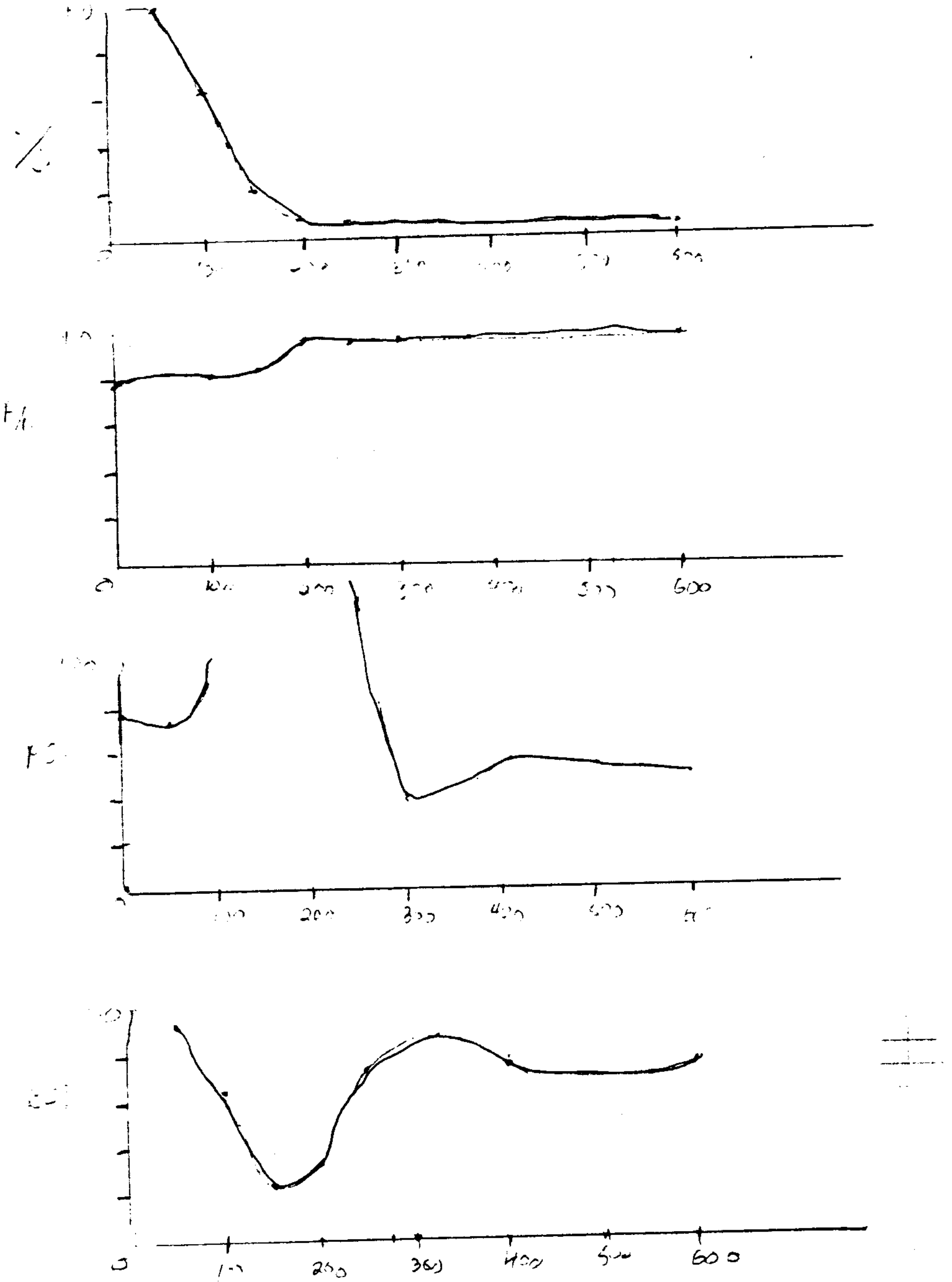
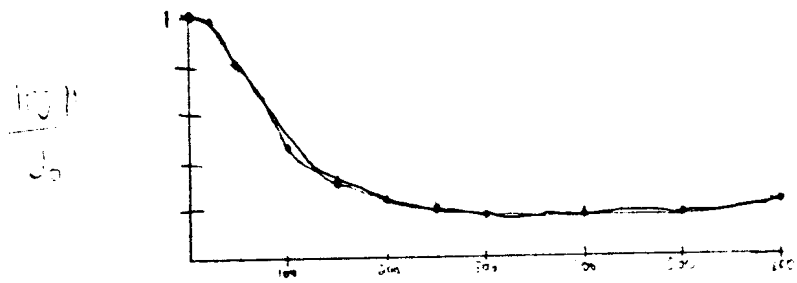
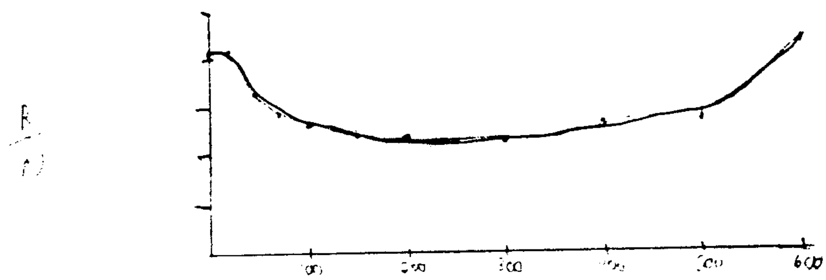
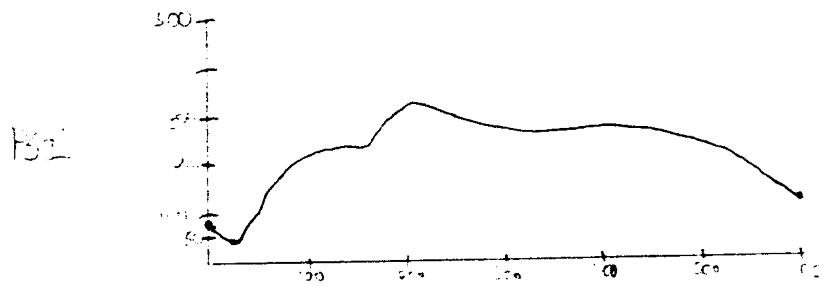
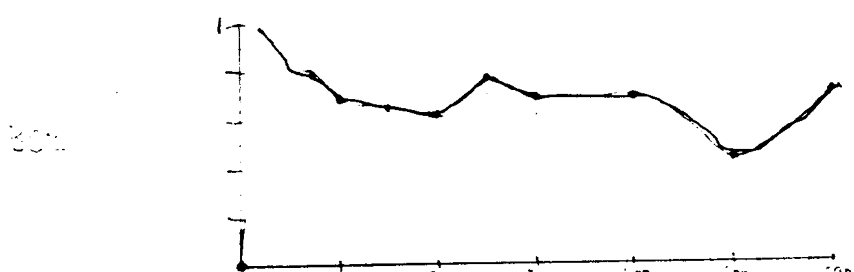


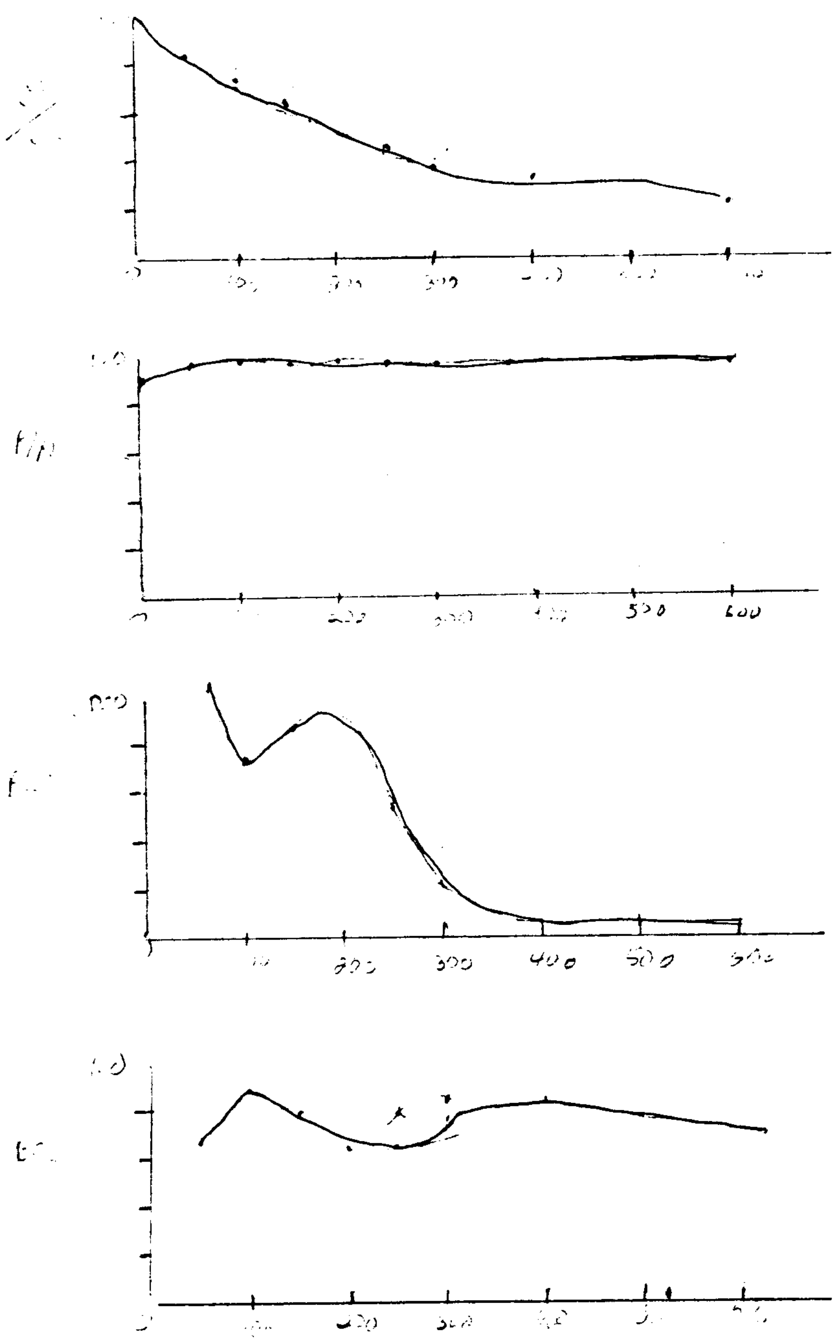
CORE HA-084



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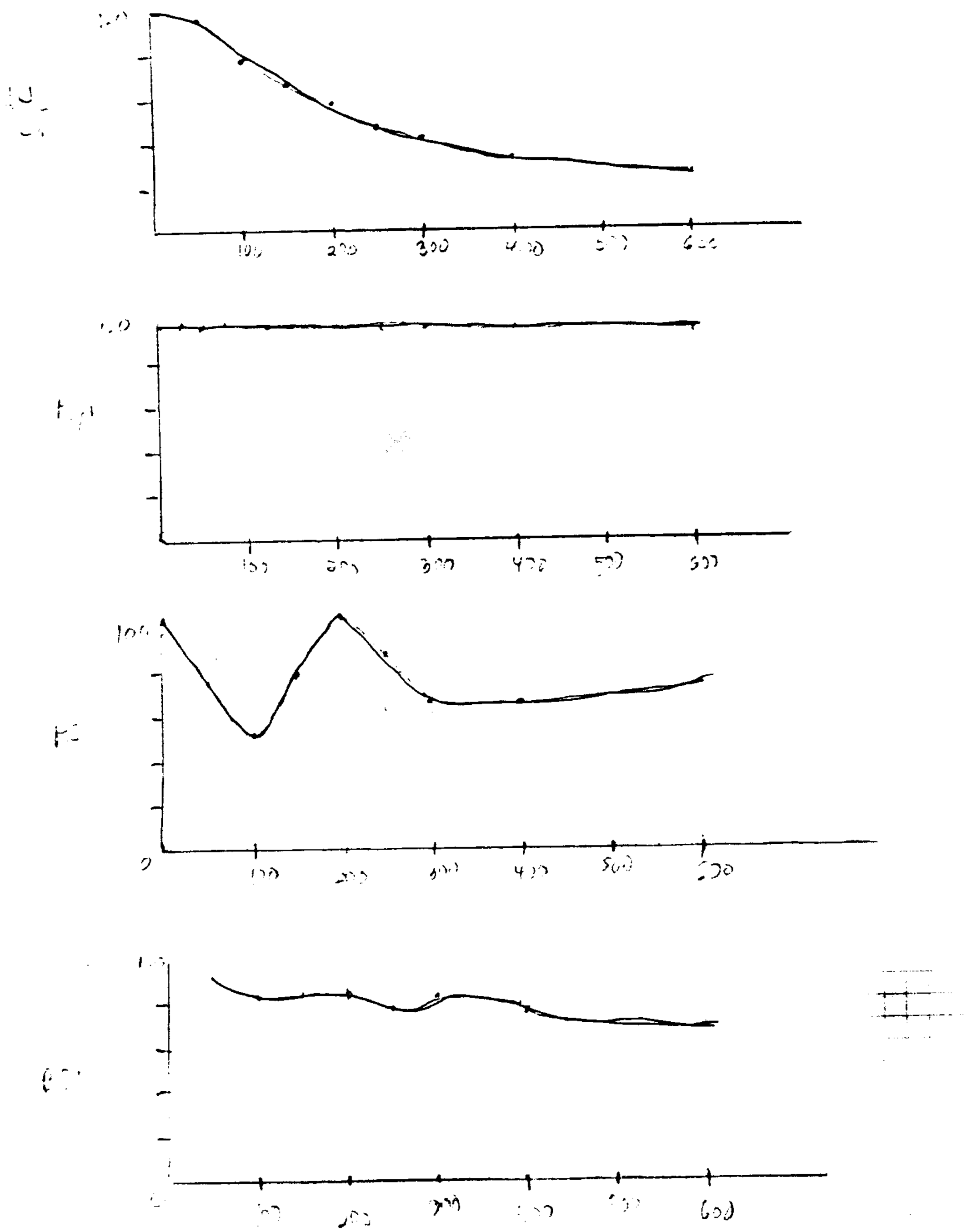
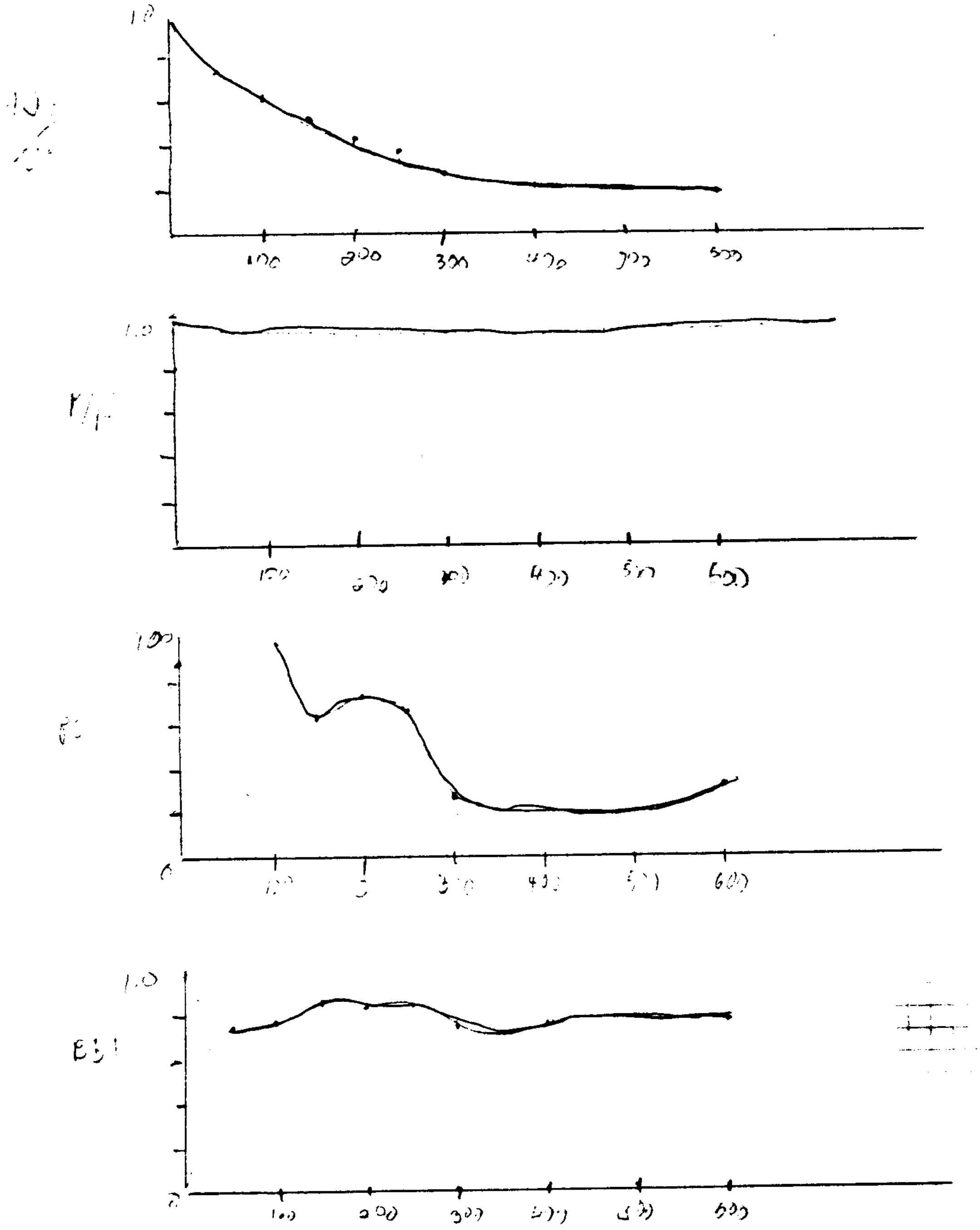
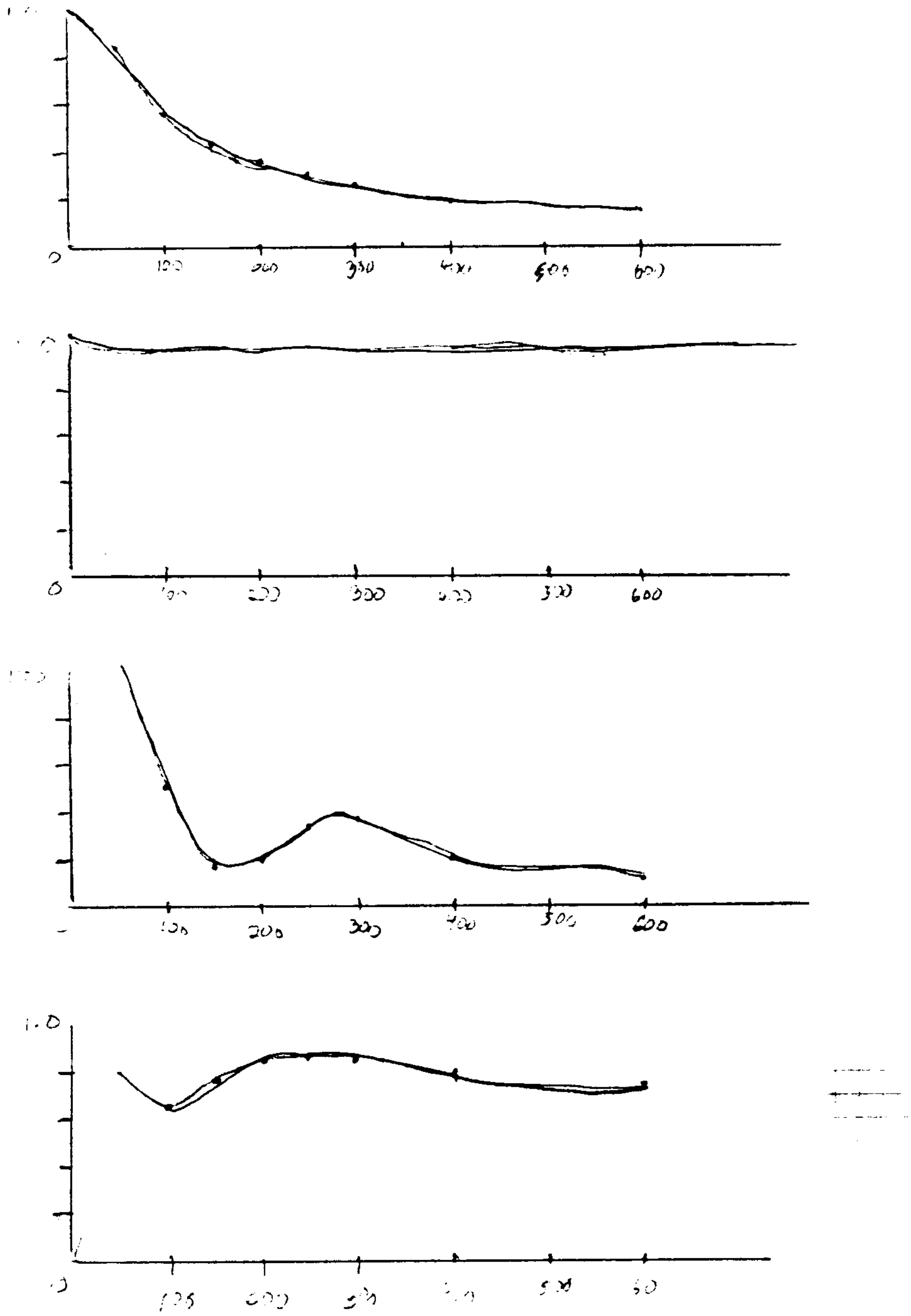
HAA-026



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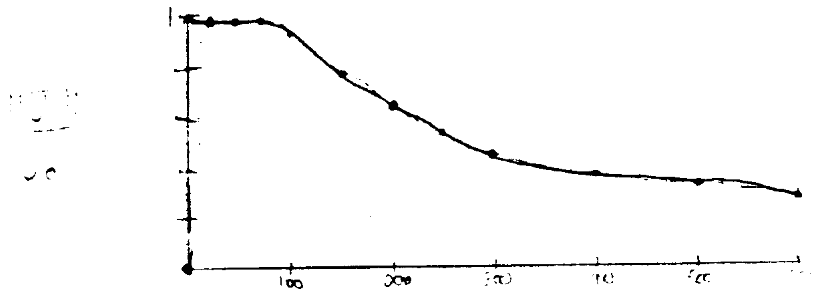
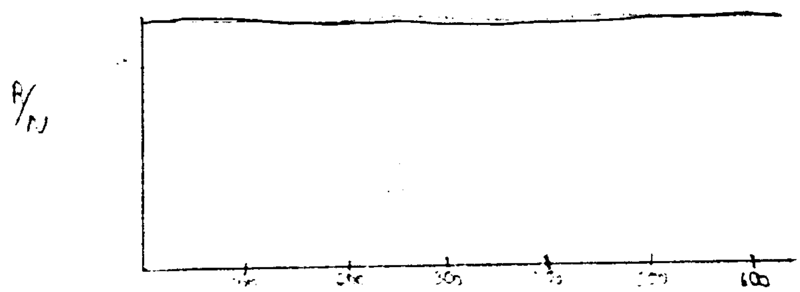
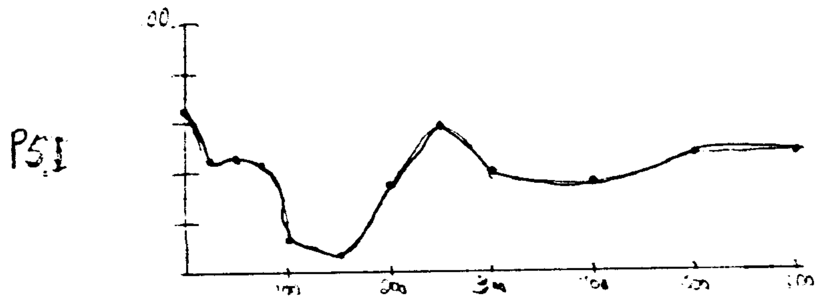
CORE HAA-029





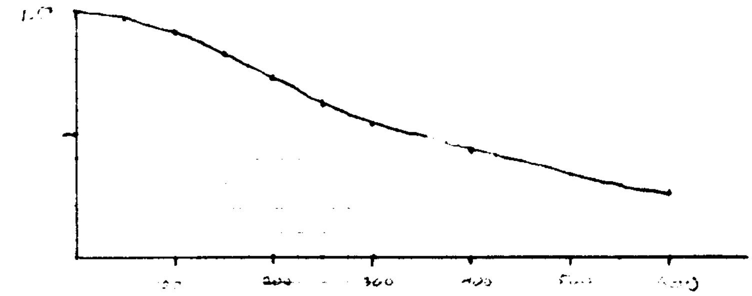


Dec Inc
172 -8

# II. Graphs of ARM Results

Results of total Anhysteretic Remanent Moment ploted by Demagnetization Stage.

Core -000

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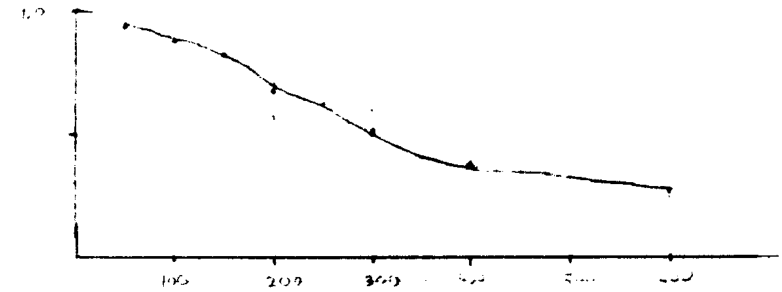


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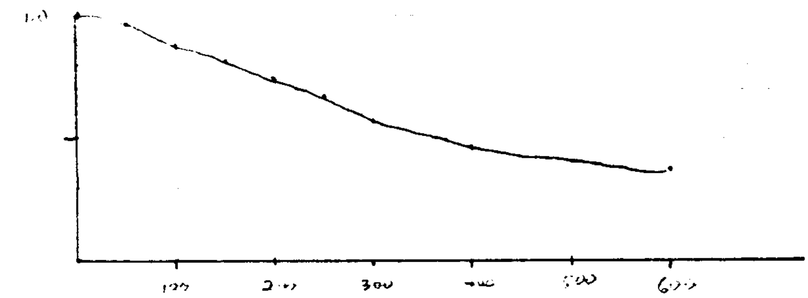
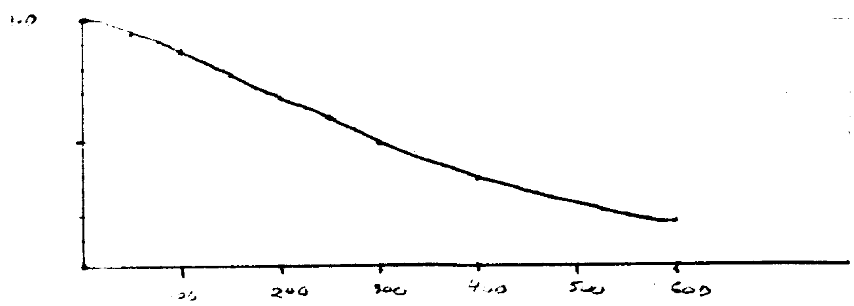
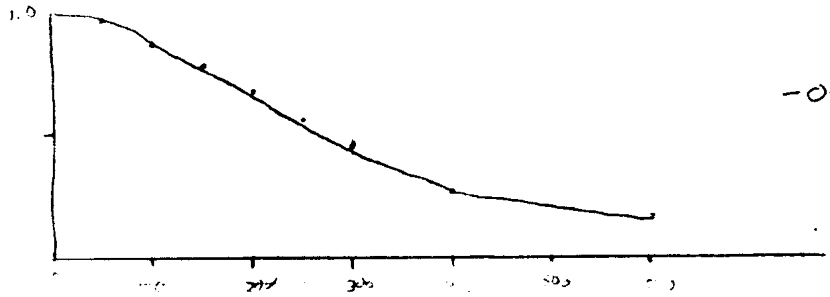



-003


-004



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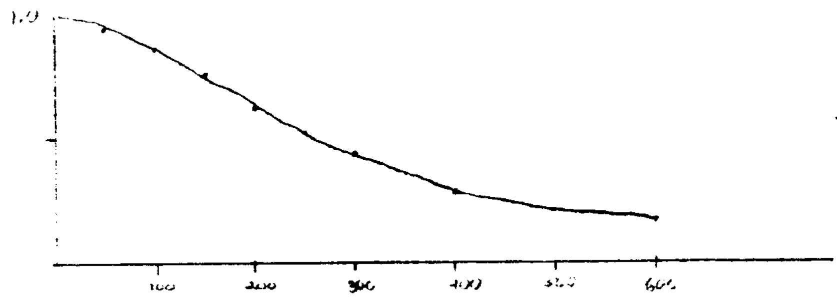


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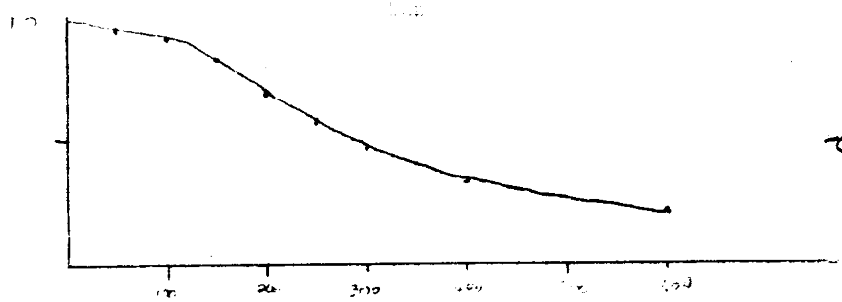


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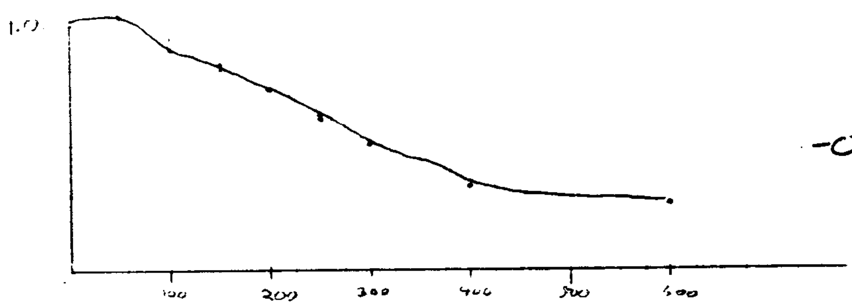


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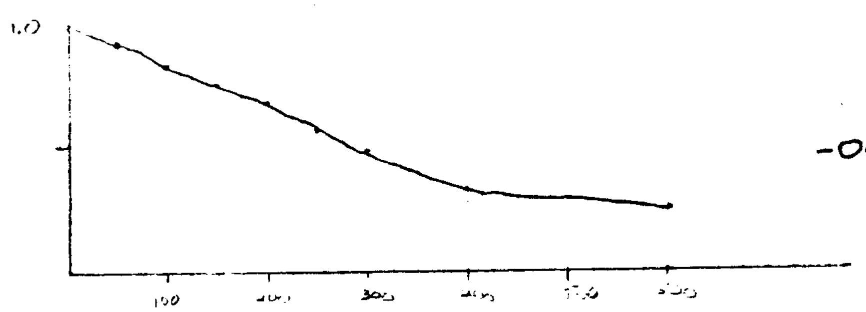


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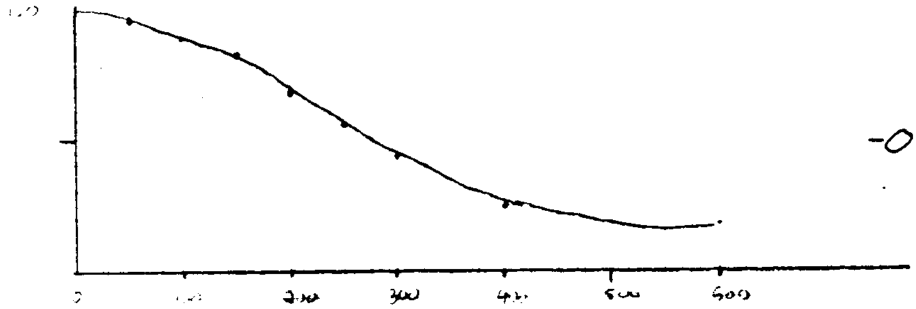


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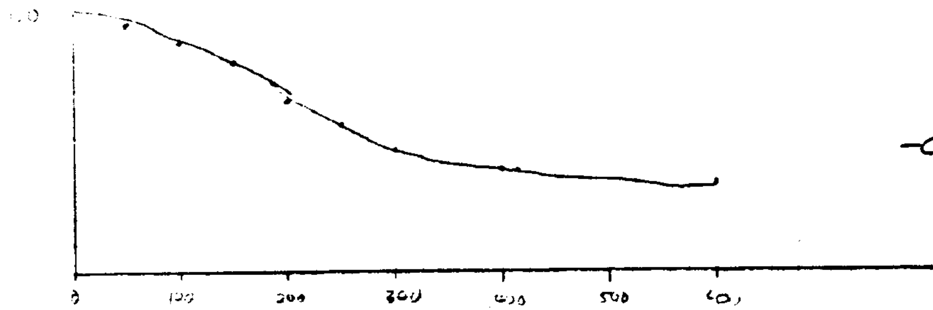


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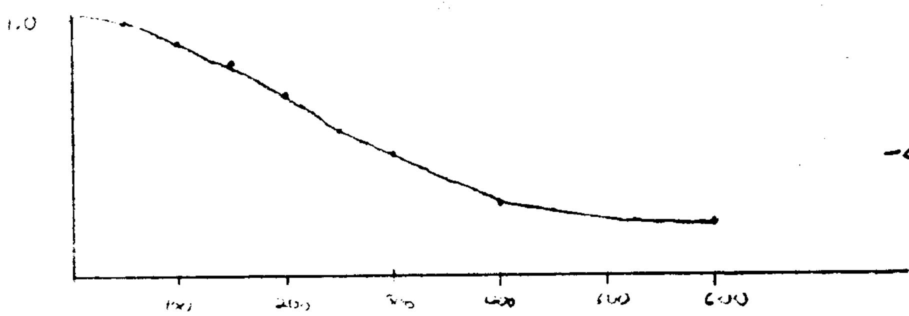


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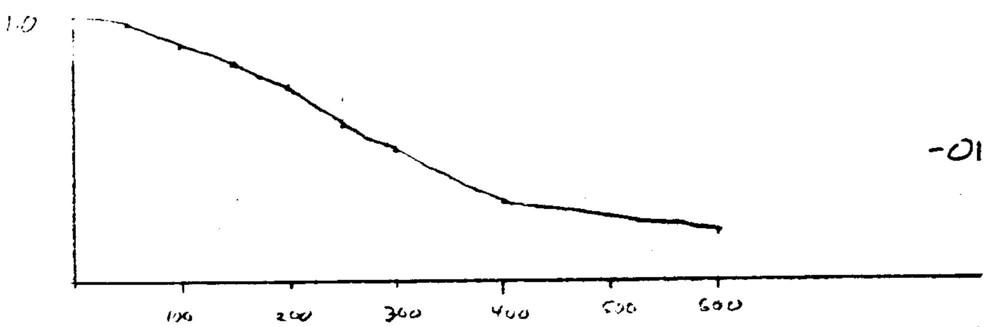


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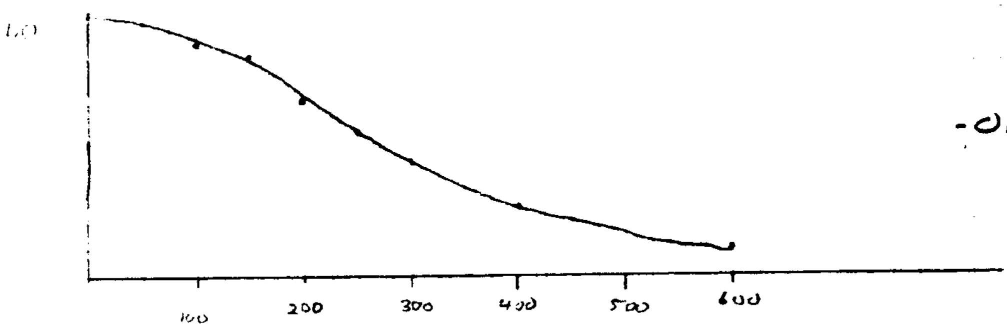


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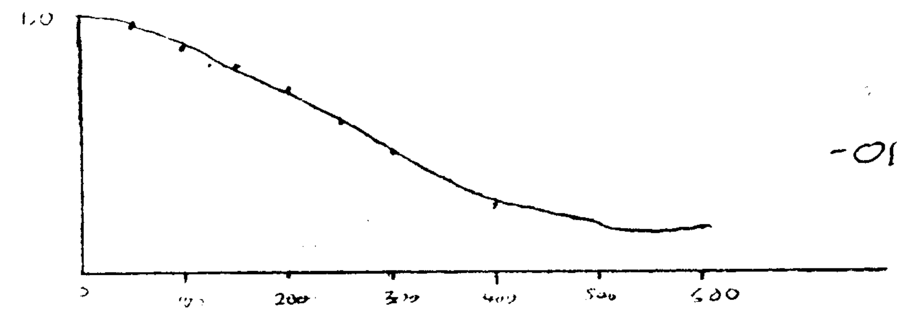


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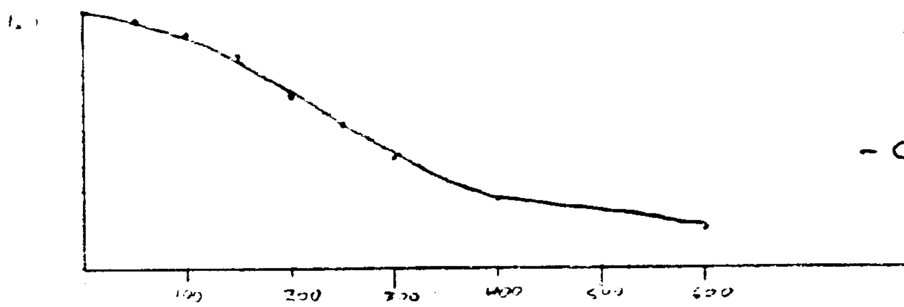


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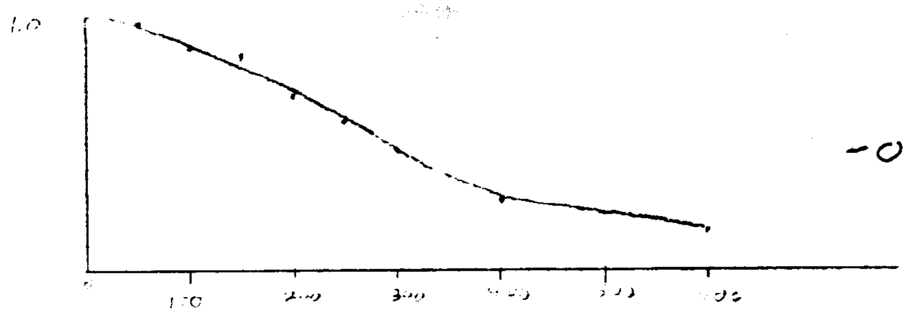


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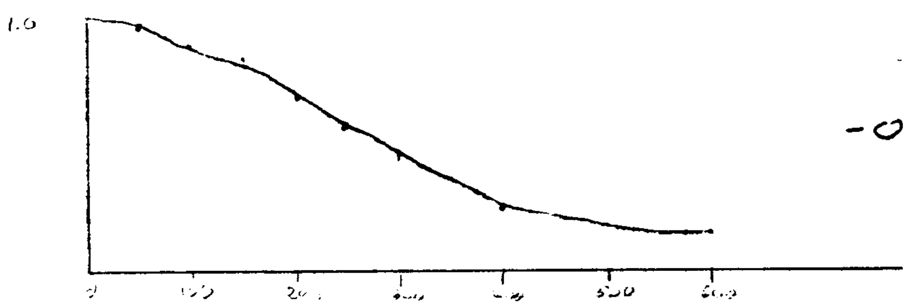


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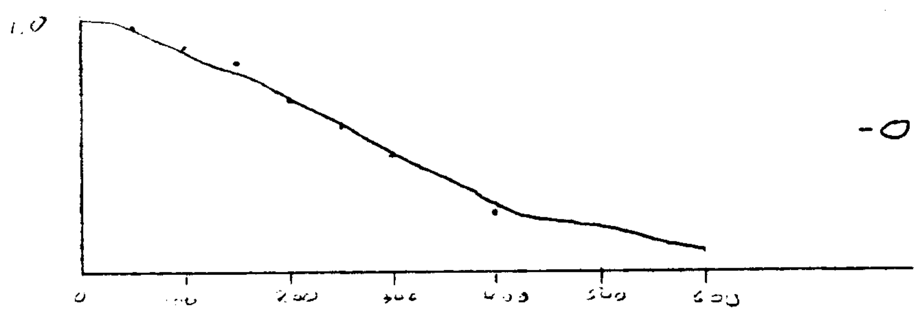


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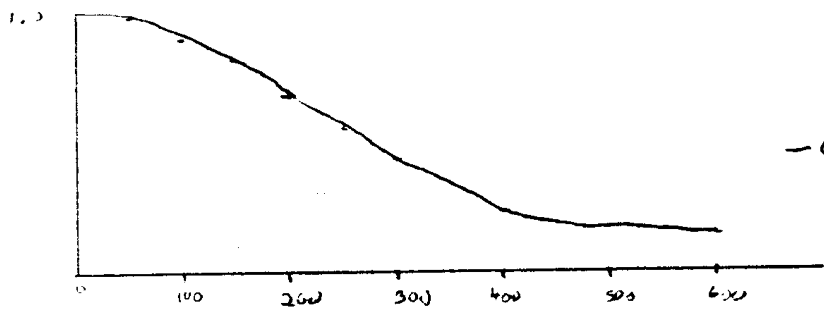


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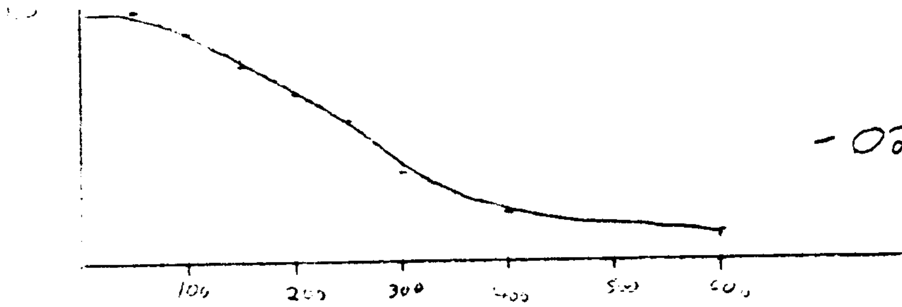

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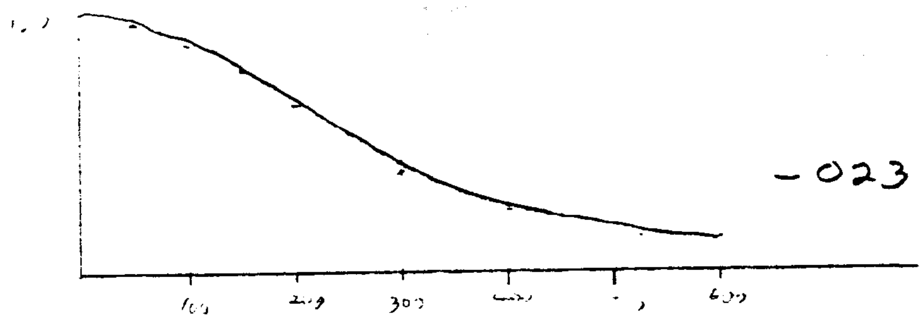

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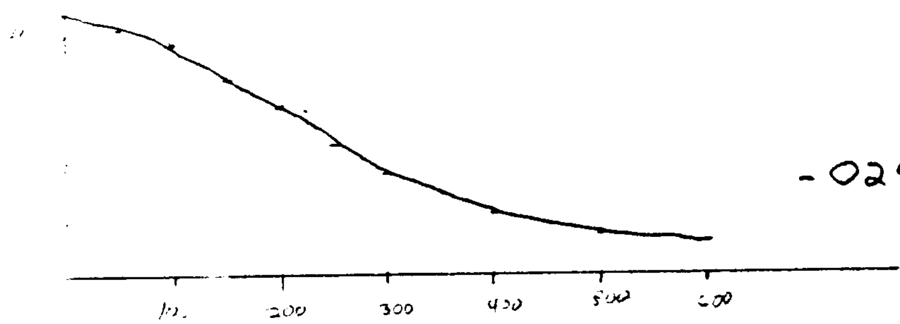


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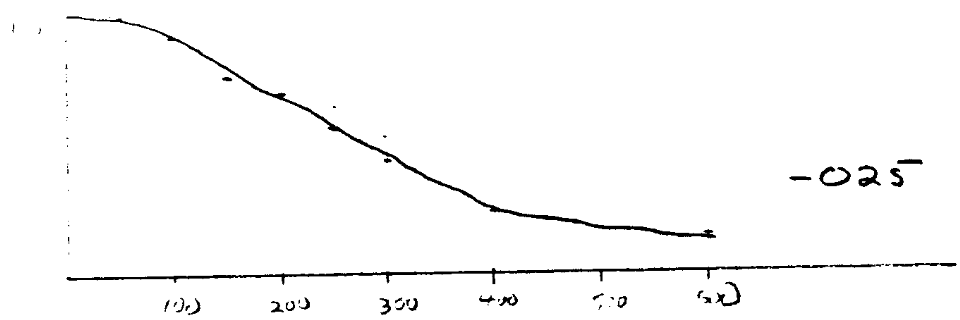


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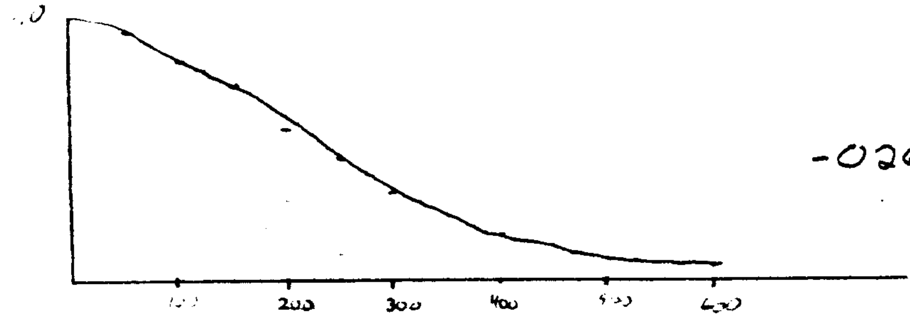


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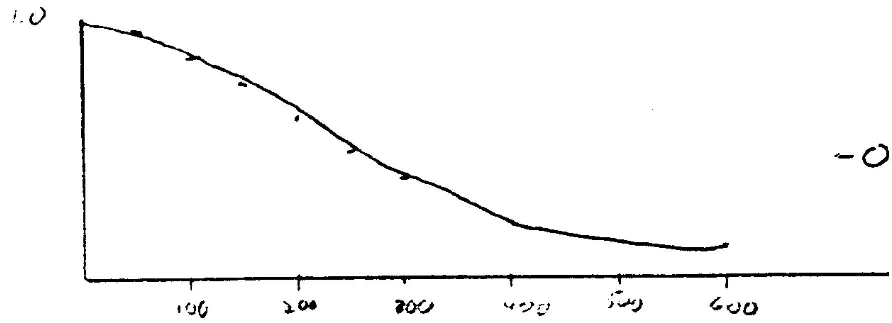


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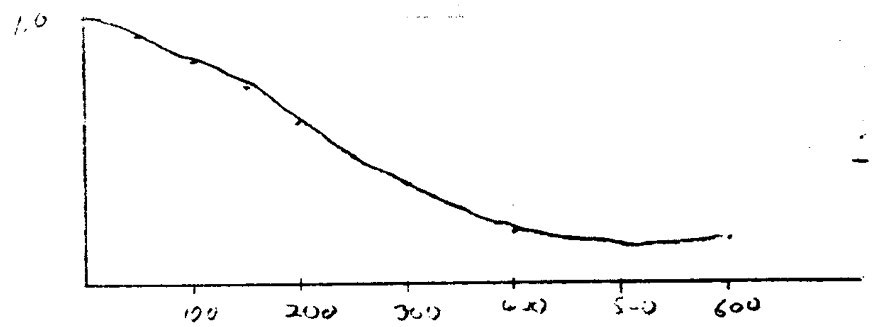


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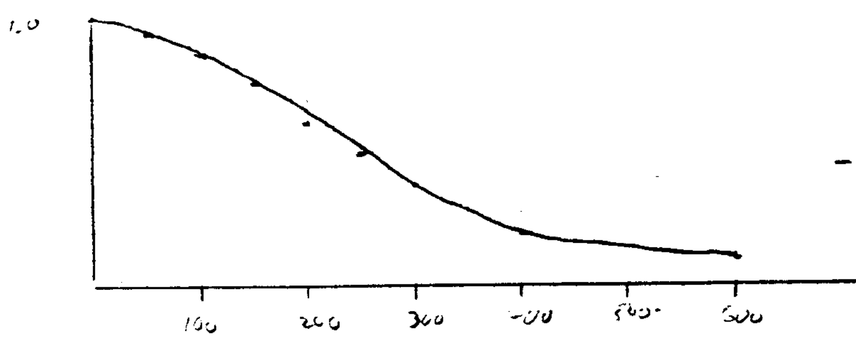


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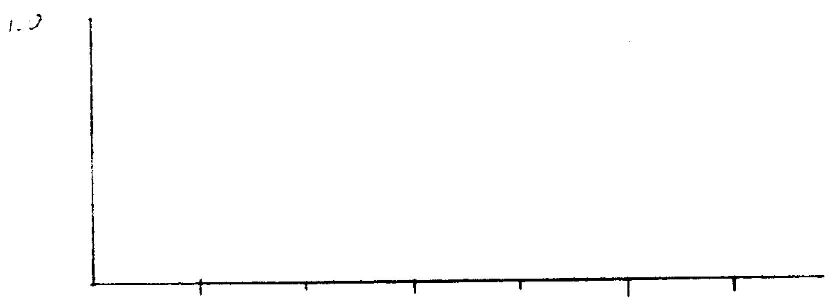

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